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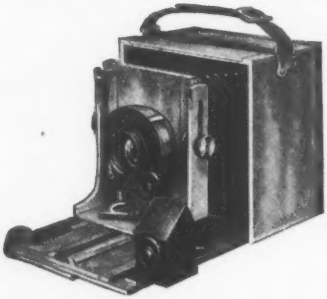

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The
GEOGRAPHICAL JOURNAL

Vol LXXVI No 3 R.G.S. *September 1930*

ISLAND-REEFS OF THE QUEENSLAND COAST: *A paper read in part at the Evening Meeting of the Society on 16 December 1929, by*

MICHAEL SPENDER

PART I. LOW ISLES

"There is not a part of Natural History more curious, or perhaps to a navigator more useful, than an enquiry into the formation of islands. The origin of islands in general is not to be discussed: but of low flat islands in the wide ocean."—ALEXANDER DALRYMPLE (*Phil. Trans.*, vol. 57, Pt. I, 1767).

THE Great Barrier Reef Expedition was sent out to do biological research at a temporary marine station; this was established in July 1928 on an island in the protected sea between the Great Barrier itself and the coast. Mr. Steers, in his paper on the Queensland Coast and the Great Barrier Reefs (*G.J.*, 74, 1929, pp. 232–257 and 341–370), has already stated how two geographers came to be attached by the Royal Geographical Society, and his paper is the outcome of the work of the first three months in Australia, when the geographical party were independent and mobile. Together, Mr. Steers and I covered a large mileage, something of the order of 2000 miles, in the motor-launch *Tivoli*. This coastwise cruise was completed at the end of November 1928; afterwards Mr. Steers returned to England and I went to Low Isles to join the main party of the expedition, which had already been busy for five months. During the eight months I was at Low Isles my time was mainly spent in carrying out a strict survey of the island; but at the same time I wanted to get as complete an idea as possible before the expedition came to an end in July 1929 of the reef system between the parallels 14° 30′ S. and 16° 30′ S.—120 miles of coast-line between Lizard Island and Cairns.

The geographical results of this period of work can be divided for the sake of convenience into those concerned with Low Isles itself, and those related to the Barrier Reef as a whole. So much more time was spent on Low Isles than anywhere else that the investigation and description of Low Isles as the representative of a peculiar type of island reef must be considered the chief part of the work, and will, together with the survey of Three Isles, which is another island of the same type 80 miles farther north, form the first two parts of this paper. The more general indications of the work will be elaborated in the third part.

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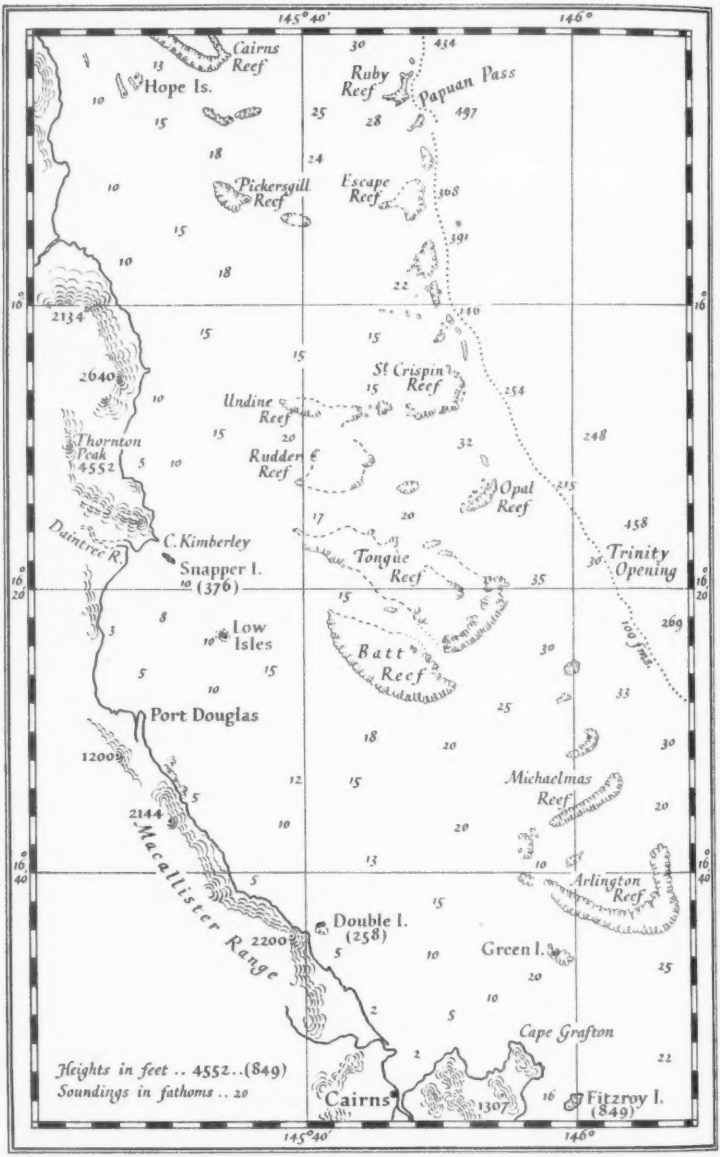


Fig. 1. Sketch-map of part of Queensland Coast and adjacent Reefs, showing position of Low Isles with respect to Barrier Reefs and Trinity Opening: from Admiralty Chart 2924

Now from the geographical point of view the expedition was exceedingly fortunate in that the committee should have chosen Low Isles as the base for the research work. Various practical circumstances such as transport and accessibility were decisive in this matter and might have sent us to a continental or "high" island,* a mountain in the sea surrounded by a fringing reef that would hardly have been worth the labour of its survey. But Low Isles is an island altogether different, since it is simply a coral reef on whose surface certain configurations of debris have accumulated. At the north-west extremity of the reef there is a sandbank or cay, a few hundred feet long and broad, its highest parts only 6 feet above the sea at high water: this was the alleged island on which we lived. Situated on the same reef and described as the second island is an area of some 50 acres of dense mangrove: from the offing this is the more conspicuous "islet." (See Plates 1 and 2.)

"It being about the time of high water, about the time we passed it," notes Captain Cook in his Journal,† "the greater part of it lay under water." The maps, figures, and text of this paper will describe the island as it is at low water of the exceptional spring tides that in the tropics take place at the solstices. A determination of this low water-level by H.M.S. *Penguin* in 1905 was taken as datum, and all heights will be referred to this level. But it must be remembered that the reef is rarely seen exposed in this exceptional way, that normally the greater part of it is below the sea, and that the spring rise of 10 feet leaves exposed only the top of the sand-cay and the main foliage of the mangroves.

Not only did the peculiarities of the tides hereabouts dominate our choice of work, but in themselves they are interesting. They are good examples of those tides found in the tropics where the diurnal constituent due to the sun's declination is of the same order of magnitude at the solstices as the semi-diurnal constituent, which is the ordinary lunar tide.‡ Thus in July or December at spring tides the constituents are in phase by day or by night respectively, giving one splendid tide in the twenty-four hours, the other being almost masked. In December, when I started the survey, there was never a good low tide by day and the reef was hardly ever exposed at all during the daylight; this added to the difficulties.

The type of island-reef of which Low Isles is our example had been vaguely recognized by previous voyagers on the coast; the recognition of the type as a geographical entity was left to Mr. Steers, who (*loc. cit.*) stated generally that the ground plan of any one was very similar to that of any other. The type may be characterized by the two distinct plant associations borne on the same shoal: the sand-cay flora and the mangroves. Low Isles is the southernmost of this type: it is in lat. 16° 23′ S., about 40 miles north of the port and township of Cairns. Like the other islands of the same type, it is about halfway between the reefs of the barrier and the mainland coast. Abreast of Low Isles the mainland forms a great bay: the high granitic mountains are set in ranges parallel to the coast. In the background of Plate 1 the massif of Thornton Peak (4500 feet)

*Cf. Steers, *op. cit.*, p. 244.

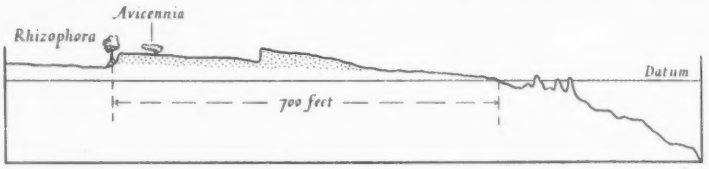
†'Captain Cook's Journal.' Edited by Admiral Wharton. London, 1893, p. 274.

‡"There are no special peculiarities of the tides at this place; there is a large diurnal element, but this is not abnormal" (Dr. Doodson, of Liverpool Observatory and Tidal Institute, in a letter to Mr. Hinks, 28 April 1930).

may be seen; in the foreground the sand-cay with its lighthouse as it appears across the reef flooded at half-tide. A great thunderstorm is forming over the mountains, and in the unusually clear atmosphere the island seems to be part of the range, though it is separated from its nearest point by 7 miles of sea.

So calm a scene would not be presented during the months from March to December. In the winter the South-East Trade Wind raises a white-flecked sea in the protected shoal waters. The Trade is no zephyr: to the northwards, particularly north of Cooktown, it blows with even greater force and persistence, often as a gale or fresh breeze for sustained periods. This sea, though it is protected by the barrier, gives many long fetches to the south-easter; and though the great steamers which pass close by the lighthouse feel nothing of it, the rough and tumble that it raises can make small craft very uncomfortable, and it is these waves which beat upon, mould, and shape the elements of the reef, throwing up the sand and shingle to form this specialized system.

We have then a protected sea, extending 15 miles from shore to barrier reefs, and in it an isolated reef. No mainland rock appears in the reef's surface features, and, though described as a group of islets, its claims to such a dignity



Vertical scale exaggerated 7½ times.

Fig. 2. Levels across inner rampart, outer rampart, and rocky reef face at E, near windward extremity of Low Isles reef: diagrammatic mangroves show characteristic habitat

are scanty. It is our concern to consider how sea, wind, and tide were able to form this system of sand, shingle, and vegetation on a coral reef.

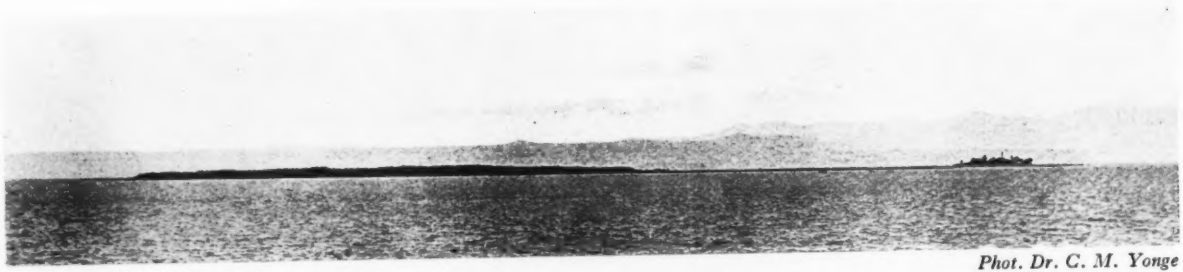
We surveyed the island in order to get a more thorough understanding of its formation: the actual attention and application required during the working of a careful survey itself led to the revelation of some interesting points. The completed plan, the result of all this work, which is published with this paper (first folding plate following p. 272), is a reduction to a scale of 1/5000 from the original survey at 200 feet to the inch (1/2400). The conventional signs used had to be developed as the work progressed, since there was no precedent for the survey of an amphibious region of this sort: as far as possible they had to be self-expressive and capable of modification from one to another according to the surface detail.

The map sheds a new light on the nature and intrinsic form of the island and modifies the first impressions. The sand-cay* which seemed so important is quite a small and insignificant member of the system; there is clearly more to be described than cay and mangroves. All but encircling the entire reef there

*A word from the Spanish "cajo" signifying a shoal, and now spelt in the West Indies "key."

Phot. M. A. Spender

1. Low Isles sand-cay seen over flooded reef flat at half-tide

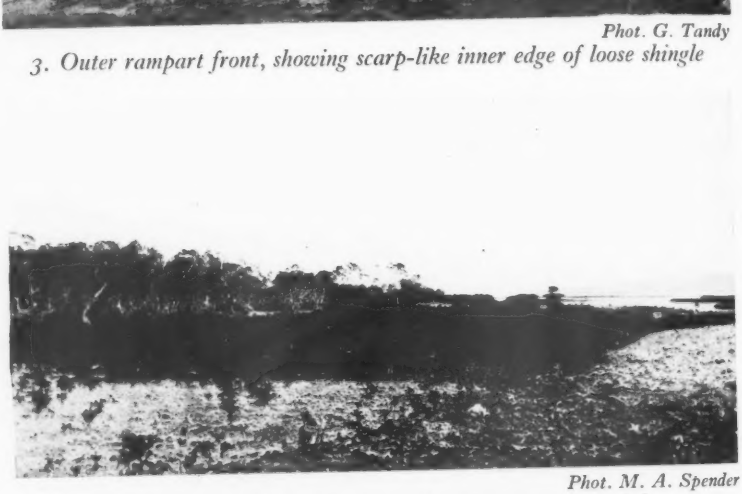


Phot. Dr. C. M. Yonge

2. Low Isles from seaward

Phot. G. Tandy

3. Outer rampart front, showing scarp-like inner edge of loose shingle



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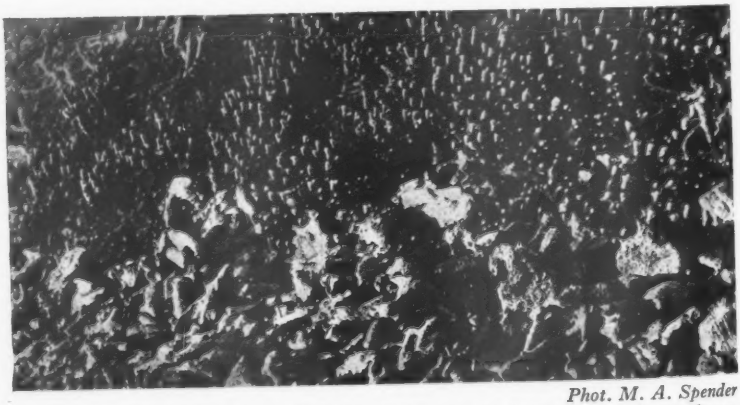
4. Scrub vegetation of inner rampart: mangroves on left



Phot. M. A. Spender

5. Shingle of rampart overwhelming living coral of moat: seen from above

is a rampart of coral shingle, which is similar to the formation described as the "puinwal" in the Dutch literature of coral reefs.* The shingle here is very different from the rounded pebbles of our beaches: it is composed of fragments and branches of dead coral, gnarled, spiky, and highly destructive to foot-gear. It is heaped up into this rampart, which is highest and most extensive at the south-eastern apex of the reef, whence it extends in each direction, becoming gradually lower and narrower.

Seen from the centre of the flat the rampart appears as a low wall, rising at its inner edge almost perpendicularly from the flat. This inner escarpment is about 2 to 3 feet high; beyond it the shingle descends in an even, gradual slope which merges into the general seaward face of the reef a little above the level of low water (see Fig. 2).

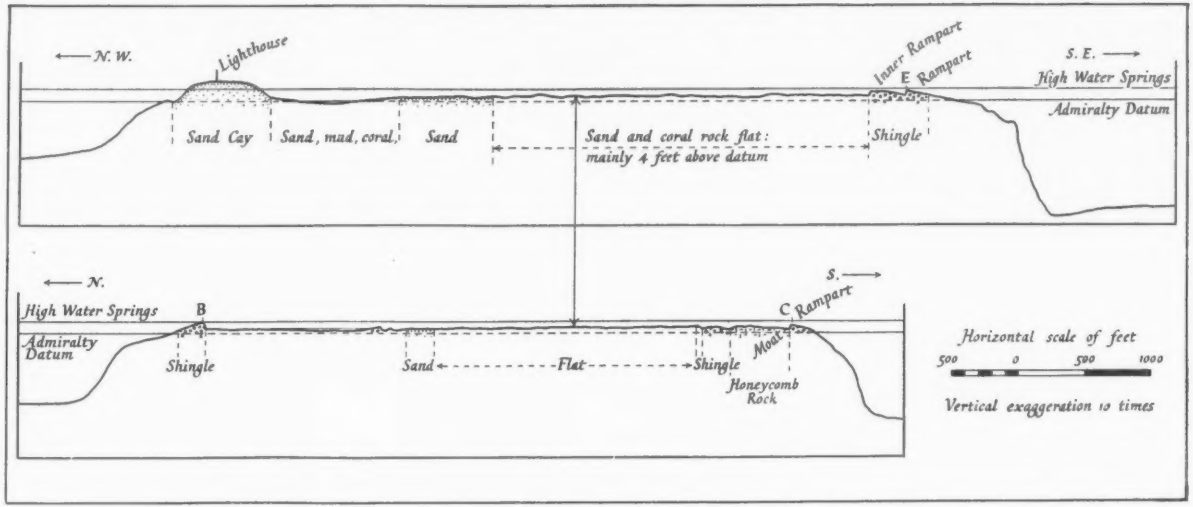
The surveyed sections of the ramparts at E will help to establish the idea of their form. Outside the shingle at low water the characteristic rocky reef face is exposed. It is a gradually sloping shelf of a fairly smooth-surfaced rock, with small pits and grooves on its surface which suggested the designation "honeycomb rock." There is in this zone only a negligible population of living coral: so the debris to form the rampart must be thrown up by the waves from some zone below datum. At the windward extremity of the reef the waves act strongly and directly, and the whole rampart is moved so that the rock to seaward of it is exposed. The notable fact is that although, presumably, this process has been going on for a long time, the shingle has not been pushed very far over the reef flat. The even trend of the rampart on the map suggests that its inward encroachment is in some way limited. It is a fact of primary importance in the formation of these islands that the detritus from the outer slopes of the reef is not thrown haphazard on to the flat, but is checked to form a well-ordered rampart.

Farther round the reef margin to leeward the waves act less directly and the rampart is less considerable and is not pushed so far forward as at E. At E the higher point of the rampart, at the top of the inner escarpment, is 7·5 feet above datum. At C beacon the summit is 5·3 feet high, the foot of the inner scarp is some inches below the level of the flat, and no rock is exposed at low water outside the shingle. The map shows from this point C to the north-west a moat of permanent water immediately within the rampart. This feature is particularly well developed on Low Isles, and was important to the biologists because of its population of luxuriant living coral. At the inner edge of the rampart the moat is about 1 foot deep, and shoals gradually on to the flat, which is dry at low water. When the tide has fallen below about 2·5 feet above datum, the water is retained in these moats, the drainage being very slight once the tide has fallen to this level. But while the tide is running off the flat there is a considerable scour along the inner edge of the rampart which may be responsible for the formation of the moats, and which is almost certainly responsible for preventing them from silting up with sand.

The section (Fig. 2) of the ramparts at E shows a double rampart system. The inner rampart there shown is characteristic of the whole of the shingle system that bounds the mangroves: it exists discontinuously for a short distance farther in each direction. On Low Isles the double formation appears to

*See references later to Dr. Umbgrove's papers.

SECTIONS OF LOW ISLES



Section from Cay to C. Beacon Vertical exaggeration 20 times

Fig. 3

Note: These sections do not comprehend the results of the borings

occur where the wave action is strong enough to throw the shingle forward on to the general level of the flat.

The inner rampart is exactly similar in form to the outer rampart already described: it shelves gradually to seaward, and inwards it descends abruptly into the mangrove swamp, or, which is equivalent, on to the flat. Its appearance and structure however differ to a certain extent on account of the protection given by the outer rampart. The shingle is very much the same material, but on the inner rampart it is somewhat blackened, as on beaches rarely disturbed by the sea; and the interstices are packed by finer sands and muds, in many places moderately cemented. While cementation conserves the form of the inner rampart, erosive processes are always at work, small quantities of shingle being stripped from the surface and carried forward to form an inner escarpment.

But on the whole the inner rampart is an undisturbed region capable of supporting a varied flora and fauna; Plate 4 shows it to be well vegetated. There is the mangrove of the shingle, *Avicennia*, some shrub colonies of *Aegialitis*, and extensive mats of a fleshy creeping plant, *Sesuvium*. The area has the appearance of being established and secure.

In this respect the outer rampart differs. The shingle of which it is composed is loose, save for the slight binding of fragments of very irregular shape. It supports practically no life: the few binding and encrusting seaweeds that live on the shingle are insufficient to stabilize it. When I drove some steel stakes into the outer rampart as bench marks during the levelling work, they would, in the course of a few days, be found to have sunk slightly because at the full tide the waves agitate the upper layers of the shingle; these small subsidences gave rise to an exasperating series of closing errors the cause of which was not at first understood. Several obvious local advances of the rampart's escarpment front provided another indication of the instability of the outer rampart, and in Plate 5 the advancing shingle of the rampart can be seen to be overwhelming the living coral of the moat.

The relations between rampart and reef-flat, and reef-flat and the other surface features such as the sand-cay, the mangroves, and the boulders, can be seen in the cross-sections of Low Isles (Fig. 3); these sections are drawn from our own levels and soundings.

The sea-bottom round about the island is of soft, grey mud, fairly even; there are depths of 11, 12, and 13 fathoms at little more than a cable's distance from the low-water margin of the reef, except to the north-west, under the island's lee. Close to the coral here is a bank having only 5 fathoms over it. This shoal deepens gradually and becomes narrower farther from the island, tailing into the general 12-fathom level at a point 3 miles north-west. In the sections the discrepancies of depths can be seen; the first shows a noteworthy feature in a 15-fathom trough close to the windward face. In all positions there is a characteristic shape of the submarine profile, interesting because it is involved in any discussion of the nature of a coral reef.

The reef-flat maintains within its eastern part, that is within the area bounded to the east by the rampart and to the west by a line continuing Tripneustes spit to C beacon, a remarkably even level of 4 feet above datum (mean sea-level is 4·7 feet above datum). On the other hand, the area described to the north as the sand-flat, and to the south as the Thalamita flat, is on a lower plane, between

Section from Cay to C. Beacon. Vertical exaggeration 25 times

Fig. 3

Note: These sections do not comprehend the results of the borings

2·5 and 3 feet above datum. Its structure and population are different from the 4-foot flat. The two levels are shown in the third of the sections given, which is from the sand-cay to C beacon. These sections also make it clear that the word "lagoon" is not properly associated with such a reef type. The word implies reef-enclosed or partially enclosed water: in its common usage a few fathoms' depth is implied. It is misleading to describe as a lagoon or pseudo-lagoon an area which dries by some feet at low water.

The sand-cay is at the northern corner of the sand-flat; it is small and low as compared with many cays associated with other such reefs of no greater extent. The cay is built of a fairly fine coral sand; about the beach exposed at low water it is cemented, to a small depth below the surface, to form a sand-rock, the usual beach rock of tropical shores. A sand-cay is a structure whose stability depends on the equilibrium of various opposing forces brought into play at the leeward extremity of a reef. During the steady south-easterly Trade weather the position and shape of the cay are rigidly determined; although the sand is hardly bound at all, the stability of the cay during normal conditions is considerable. Directly abnormal weather sets in, the cay as determined by south-easterly weather is an unstable structure, depending only on its inertia to resist being shifted to another position on the reef.

The cay is about 700 feet long at low water, and its highest point is only 16 feet above datum. When at spring tides the sea rises to 10 feet, there is left only a bare 6 feet of "freeboard"; this, it may be noted in passing, is less than would be required by the Board of Trade for a laden vessel of the same length along the water-line.

Nevertheless, the sand-cay was the only habitable part of the complex: for this reason the huts of the expedition were built on it; a lighthouse has stood there for forty years and would have been our refuge in case of a cyclone. There is a tradition, probably true, that within living memory its 3½ acres of usually dry land have been awash. We were fortunate however in finding it a consistently comfortable and secure sandbank.

The contours of 4 feet and 8 feet above datum (at the time they were mapped) are drawn in. The 12-foot contour was not followed round, being rather involved with the buildings, but it corresponds roughly with the vegetation line. The only remaining detail is the sand rock, which is marked in blue striations corresponding with its strike. This rock is not part of the essential structure of the island system: it is a surface feature occurring frequently on tropical beaches, and provides an interesting problem in calcium chemistry. In Plate 8 the rock can be made out at the base of the bare sand slopes of the cay.

The mangroves have been mentioned once as forming the second of the alleged islets of the system, and again as a feature of the 4-foot flat. They are such an exceptional and surprising phenomenon in this position, 7 miles out at sea, exposed to wind and weather, that it is necessary to have a clear idea of what exactly is there. In Plate 8 they can be seen as a dark belt beyond the reef, and can at once be recognized by any one who has seen the mangroves of a tropical coast. Now this word "mangrove" does not mean any specific tree: it is a botanist's word for the estuarine association of the tropics.* Certain

*Willis, 'Flowering Plants and Ferns,' vol. i, ed. i, 1897, p. 188, says: "Of the various formations which grow on tropical coasts, the chief is the mangrove formation, found

characteristic genera have come to be known as mangroves; but the important connection of the word is with the sheltered, steamy, tidal, mud estuary of a tropical river. And therefore this area on the reef has given surprise to botanists generally. It is indeed a strange experience to see what appears to be an ordinary English wood or coppice standing in an angry white-flecked sea, without any obvious support or protection. On seeing it for the first time in rough weather one has to remind oneself that it has already endured several south-easterly gales.

The mangroves stand on the level of the flat, where they have formed a swamp. The swamp itself is a region which can only be explored through its open glades and passages. "Dense mangroves" cover extensive areas, and here, as elsewhere, form with their buttress roots an impenetrable tangle of soft stinking mud. The open glades, sometimes harder floored, and usually flooded, can be attractive and picturesque places; there is a pleasant hush among the trees that is welcome after the unceasing roar of wind and surf which can be so fatiguing in the open. The explorer can fancy himself in the middle of a continent until the irritation of the sand-flies makes him heartily thankful to get back to the open reef.

The mangrove of the swamp is *Rhizophora mucronata* Lam., known locally as the black mangrove.* It is interesting to note that since it is fringed by a zone of *Avicennia officinalis* L., known as the white mangrove,† which grows, as already stated, on the inner ramparts, we have the usual shore order reversed. The question of the distribution of mangrove species is, of course, one of levels. The Rhizophora here is the mangrove of the swamps, the low-level tree: so in a shore association it will be the outermost and fringing species unless there is a form belonging to a yet lower zone. In the mainland associations that we were able to see, Rhizophora was the outermost. Avicennia belongs to a higher and drier zone: and in a mainland association forms thickets in the middle of the Rhizophora. Here the habitat of Avicennia is supplied by the rampart which forms a pile of shingle bordering the swamp.

The whole of the swamp area is flooded by the tide once or more every day, and for the most part never dries: at high water only the main foliage is above water. It is fair to say that there is no cay, nor any island for that matter, but only mangroves. There is a good *prima facie* case for supposing that the existence of the mangrove swamp is dependent on the protection given by the shingle rampart. But the working out and examination of this point of view, and of the relations between the mangroves and the shingle, will be delayed until the description of the reef is more complete and the similar system at Three Isles is available for comparison.

At the north-west margin of the Low Isles reef, between the sand-cay and Asterina spit, there is a tract of boulders. This is rather surprising, because the north-west is the most sheltered strand of the reef: one would have expected a zone of the largest debris to be associated with the most violent surf. There

covering the muddy swamps at the mouths of rivers and elsewhere, over which the tide flows daily, leaving the mud bare at low water. The plants found here present a great similarity in habit and other features, though belonging to different families."

*'Comprehensive Catalogue of Queensland Plants,' F. Manson Bailey. Brisbane, 1912, p. 175.

†*Ibid.*, p. 382.

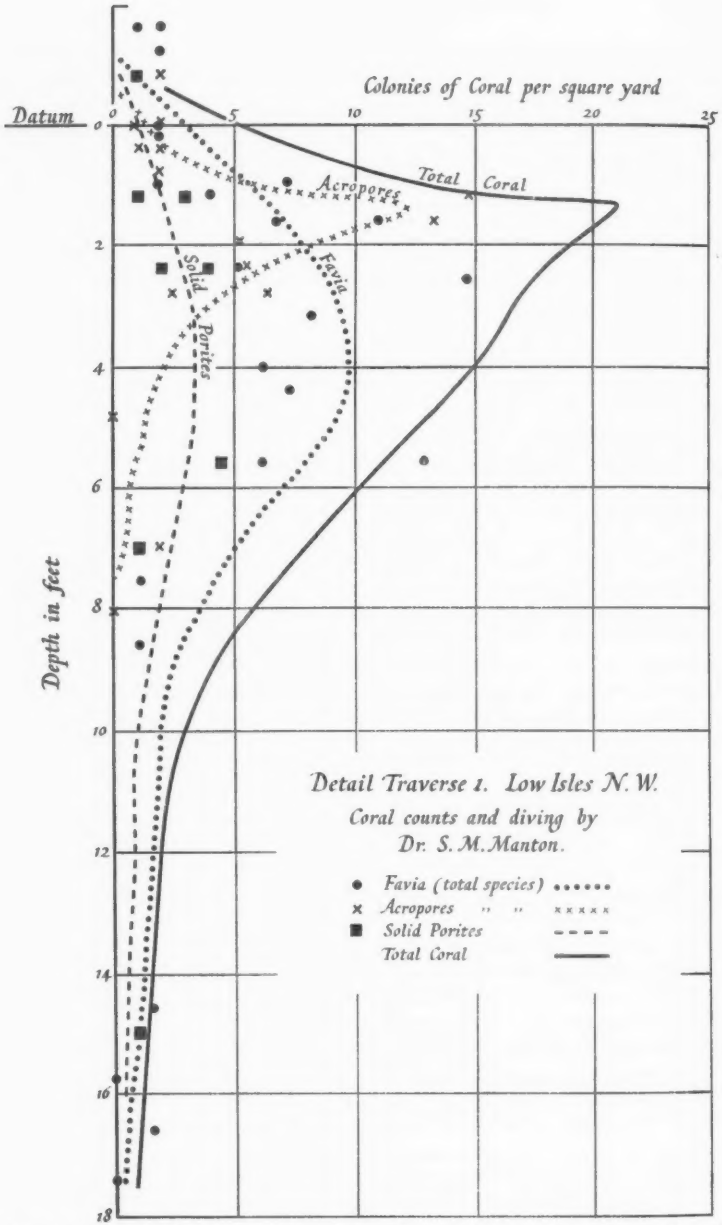


Fig. 4. Graph showing relation between abundance of coral growth and depth seaward of boulder-zone, Low Isles

seems however to be an explanation. The sea next this tract and to leeward of it is usually so sheltered as to be completely tranquil. In this sheltered water grow many coral heads. These are pinnacles of coral rock rising from 10 feet or so below low-water springs and topped by a cap of luxuriant living coral. As they rise towards the surface the conditions for the growth of living coral improve. We have a quantitative estimation of this in the shore party's graph (Fig. 4), made by counting the coral colonies at different depths in this very position. Although the determination has only a rough accuracy, since the conditions of the experiment were difficult, the indication is clear enough. The optimum depth for the coral is at about 2 feet below datum. The consequence of this increased growth from the bottom towards the surface is that the upgrowing pinnacles become top-heavy and unstable. During our diving excursions we sometimes saw a spreading cap of rich luxuriant coral balanced on an inadequately slender trunk. From a boat at low water these coral heads can be seen awash, a profuse display of form and colour. Should it blow very strongly from a northern quarter, the unexpected sort of thing that happens during a tropical disturbance, these coral heads, so accustomed to tranquillity, are taken completely by surprise and a zone of stranded boulders on the reef edge follows. At the windward arc of the island, the perpetual pounding of the south-east Trade prevents the formation of any specially unstable coral growths, and a spell of extra rough weather has few opportunities to wrench up such blocks as are thrown upon the leeward strand. But in the quiet water of the north-west, growth piles upon growth unchecked.

In passing it is worth making a comment on the use of the word "nigger-head" or "negro-head"; at present both in the literature and general usage it seems to have two meanings. Usually it has been applied to the large boulders which stand, often isolated, on the surface of reefs; but it has also been used to describe the coral heads of the above paragraph. Flinders' definition is:

> "The negro heads were lumps which stood higher than the rest; and being generally dry were blackened by the weather; but even in these, the forms of the different corals, and some shells, were distinguishable."*

This might apply to either or neither of the foregoing categories. Reading Flinders' definition recalls to me the occasional skull-shaped colony of such a coral as *Favia* or *Symphyllia*, recently dead and blackened, standing out from the top of a coral head for all the world like the head of a swimming black-boy. However, by the terminological confusion which has taken place, scientists have called them nigger-heads while they lived in the deep water and nigger-heads again while they lay decaying on the reef surface, riddled by a thousand boring organisms. The circumstances seem to justify abandoning the word for the present, and using the words "coral-head" and "boulder" for the two meanings respectively.

Dr. Umbgrove,† in his account of the coral reefs in the Bay of Batavia,‡ notes

*Flinders, M., 'A Voyage to Terra Australis,' 2 vols. London, 1814. Vol. 2, p. 88.

†Recently appointed Professor of Geology and Palaeontology at Delft in succession to Professor Molengraaf.

‡"De Koraalriffen in de Baai van Batavia" (Summary in English). Dienst van den Mijnbouw in Nederlandsch-indië. Wetenschappelijke Mededeelingen. No. 7, 1928, p. 33.

specially the absence of nigger-heads on those reefs and islands. He has since told me that it is true in general of the reefs of the Java Sea that there are no large boulders thrown on to the flats, although the monsoons blow with great force. But it is especially interesting, and at the same time rounds off what has already been written, that in this part of the Dutch East Indies there are no tropical disturbances or cyclones. And further that in these waters coral boulders thrown up by the sea are known only in the Sunda Straits where the coast was swept by the devastating tidal wave caused by the eruption of Krakatoa.

Not very much is known of the outer submerged slopes of the reef. Profiles were made from lines of soundings at five points about the reef; in two of these, that along the Detailed Traverse at the north-west and that outwards from E at the south-east of the island, the points were fixed with special marks for the sake of accuracy. In addition to sounding, we made some dives (with a helmet of the type used by Dr. Beebe) at one or two outside positions from a small and inadequate boat—a proceeding which was often rather unpleasant. The submarine slopes are rocky the whole way round the island except where the sandy anchorage makes a break in the plan of the reef. One walks along the bottom between great columns of rock over a floor which may suddenly drop into a deeper and darker space. The décor is of brightly coloured coral; fish move gently through space and alcyonarians sway with the seas above: one's appreciation of all this beauty however is somewhat checked by the fear of what horror may be concealed amongst the impenetrable shadows.

The characteristic shape of the reef profiles is convex above and concave below. The steepest slope occurs at the point of inflection between the curves, and the steepness varies with the position about the reef, the values being 12°, 15°, 16°, 17°, and 34°; this last value, the steepest, was at E, the windward apex of the reef, where also is situated the curious trough in the mud at the base of the slope. Various profiles have been taken formerly for reefs descending into deep water, but so far as I know no work has been done on reefs rising from a shallow sea bottom, with which these may be compared. To any one accustomed to watching breakers, there is no question as to the marked difference from a deep-water reef, for the seas break at the edge of Low Isles reef as on a gently sloping sandy beach of our coasts where the waves, regardless of their size, break some distance from the shore; the sudden rise and smashing collapse of the breakers about an exposed reef confirm the steeper slope into deep water which has been indicated by soundings.

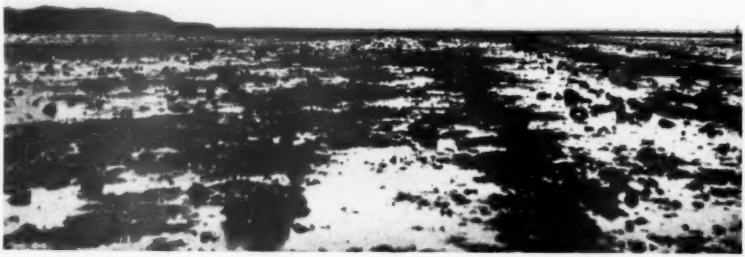
PART II. THREE ISLES

When the sun is in the northern hemisphere there is a sequence of very low tides by day, occurring once in every month for about a week at the time of either full or new moon. This effect is most marked in the months May, June, July, and August. Since the expedition was to return to England at the end of July 1929, three opportunities were available to us to make some acquaintance with the reefs other than Low Isles. In each case we should have about a week of good working days; before and after this period would be a week of neap tides, during which practically no work could be done on the reef, which would

Phot. J. Colman

6. Mangroves seen over reef flat from top of Low Isles lighthouse

Mangroves Promenade S.E. Beacon



Phot. M. A. Spender

7. Ridges in honeycomb rock, Three Isles

Phot. M. A. Spender

8. The promenade, Three Isles: 5-foot platform of hard conglomerate to windward of island

Phot. R.A.A.F.

9. Vertical air photograph of part of outer rampart outside mangroves, Low Isles

Phot. M. A. Spender

10. A forest on a coral reef: interior of mangrove swamp, showing well-grown Rhizophora

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be almost continually under water. This fact, that there were not many days in the year in which it was possible to attempt the kind of work we wished to do on a coral reef, must be remembered as a dominant limitation of fairly general application in this branch of field work, where already the mischances of wind and weather and the difficulties of transport are sufficient encumbrances.

We (and here I refer to that group of the expedition designated the "shore-party") had formed a point of view about the work on Low Isles that made it very necessary to have as complete a survey as possible of another island reef of the same type: we were hardly in a position to derive the principles which are responsible for their formation from a single case alone.

Three Isles, 80 miles north of Low Isles, is in latitude 15° 07′ S., and is the southernmost of a group of three such island-reefs (Two Isles, Low Wooded Island, and Three Isles) in the bay between Capes Flattery and Bedford. Mr. Steers and I had previously visited this island and found it most interesting; in fact, Fig. 5 of his paper is largely based on this place. We decided to essay the survey of Three Isles in May.

New moon was on 9 May 1929. The motor-launch *Luana* left Low Isles on the morning of May 1 in fine weather, bound for Cooktown. It was not until May 3 that the party with the equipment, stores, and water were landed, not without difficulty, through the surf on to the sand-cay. The party consisted of Dr. and Mrs. T. A. Stephenson, Messrs. J. S. Colman, T. Iredale, and myself. Dr. Stephenson and Mr. Colman were to carry out the zoological part of the survey, Mr. Iredale to make a collection of the mollusca, and Mrs. Stephenson to help me with the survey. At the time *Luana* left us it was blowing a moderate south-easterly gale, *i.e.* the Trade wind, which continued day and night during the whole seven days spent on the island.

Three Isles is a single island-reef system like Low Isles. It is placed similarly with regard to the reefs of the Barrier system and the mainland. It is subject to the same tides, and the south-east Trade is the dominant feature of the climate, though here the wind blows fresher and more persistently. Sea depths about the island correspond exactly and the bottom is muddy. Save then for the greater strength of wind, we are dealing with a complex which is subject to precisely the same external conditions as Low Isles.

Working at a forced pace we were able to make a map on the scale of 300 feet to the inch, on a tacheometric base line and a rough theodolite triangulation. The whole survey was carried out according to a programme made before coming to the island. Six full days was a scanty allowance and left no time for the survey of the mangrove area.

The map (see second folding plate following p. 272) shows the reef of Three Isles to be much the same size as that of Low Isles, but of a more regular plan. The type features—sand-cay, shingle-ramparts, and mangrove-swamp—can be recognized at once. There are some differences in detail between the two cases, but the essential similarity in form is very striking. Three Isles will not be described here as a separate entity, but in its relation to Low Isles; it was surveyed with the deliberate idea of learning more about the basic principles common to both islands. A more detailed account of the island will be given in another place.

The sand-cay is large and in several places is about 10 feet above high water.

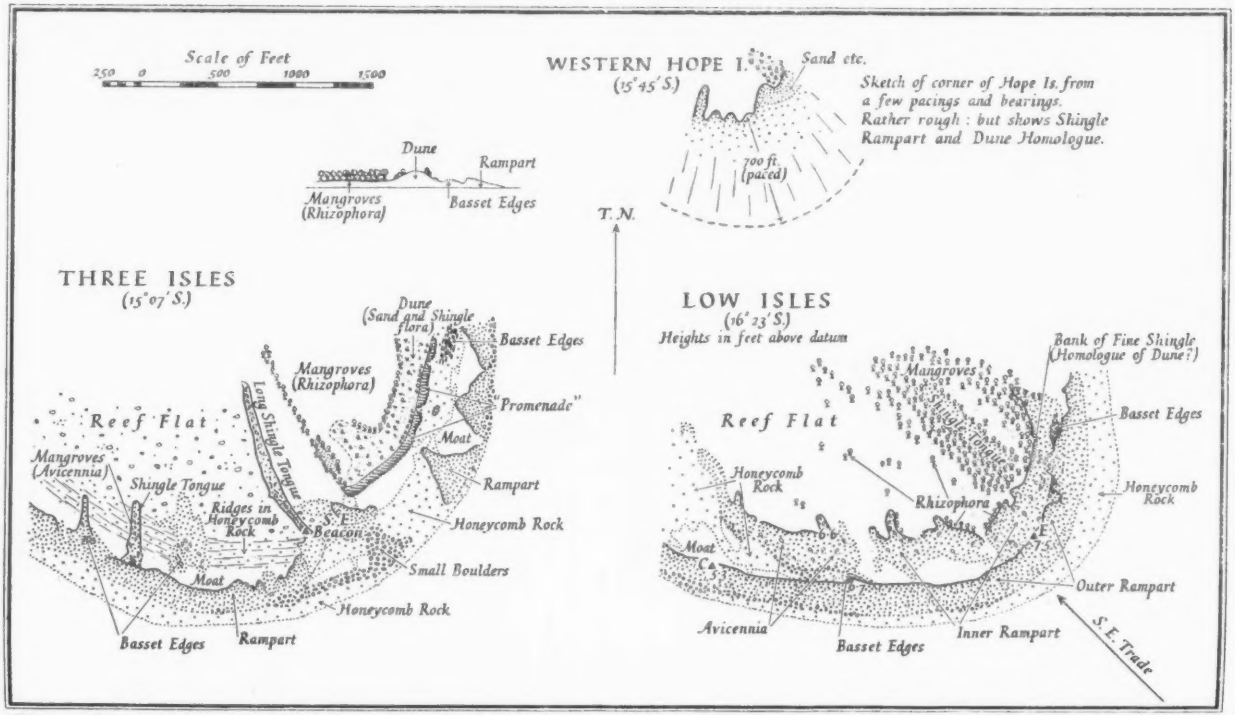

Fig. 5. Comparison, using similar conventions, orientation, and scale, between windward portions of Low Isles and Three Isles

The mangrove swamp, rather less extensive than that of Low Isles, is bounded on the west by a line of trees beyond which there are no isolated clumps or individuals. This contrasts remarkably with the scattered "Mangrove Park" of Low Isles and raises the question of how the mangrove swamp is limited. We may argue that the swamp is always progressing towards an ultimate stage when cay and swamp are in complete contact. But this keenly defined line of Rhizophora suggests the possibility that the ultimate limit of the mangrove growth in any island is determined by factors intrinsic to each case: it is an interesting but difficult problem and will no doubt be treated by Mr. Tandy, the botanist, elsewhere. The association of a "long" shingle tongue with the western boundary is suggested by the position of the so-called "earthworm" tongue at Low Isles, and again in the account Mr. Colman gave of his exploration of the mangroves of Three Isles. This well-ordered sweep of Rhizophora formed a thick hedge between an open glade and the rest of the flat. East of the glade there were dense mangroves growing in a fairly firm mud; an occasional large boulder of some long-dead astraeid coral was to be seen lying amongst the mangroves just as at Low Isles. But before the eastern limit of the mangroves was reached two ridges were crossed whose summits were above the level of high water and on which there flourished a terrestrial, rather than a palustrine, flora. In this swamp also, it may be remarked, are many mosquitoes of a ferocious species. It is possible that the formation of a mangrove swamp on any such reef as this is strictly conditioned by the system of shingle tongues overlying the flat.

Three Isles has for its third island a structure whose position and alignment on the map indicate it almost certainly as the relic of a former shingle tongue. In its present form there is on the west a fairly high platform of a hard, conglomerate formation, much eroded, that runs the length of the "island." The seaward edge is cliff-like though very irregular; the base is undercut and the surface pot-holed and covered at spring tides. East of this rocky formation is a bank of shingle, sand, and mud. The top of the bank has a flora of Avicennia and grass, and along the margin next the flat there is a strip of the mangrove Rhizophora. The whole structure is an interesting miniature of the main mangrove complex opposite, but since it is on the western side of the reef it is a mirror image.

Outside the main body of mangroves at the south-east there is another such cemented platform. It is a feature apparently without counterpart on Low Isles, occupying the position of the inner rampart. This platform, with its pot-holed but generally level surface, and abrupt outer edge, bears enough resemblance to the sea-front promenade of a holiday resort to justify its name. The superficial appearance, in particular the pitted surface, resembles remarkably those eroded coral limestone formations of the coasts of certain islands in the Red Sea illustrated in the *Journal* for January 1930 (vol. 75, pp. 27–34). Between its exposed surface and the mangrove swamp there is an accumulation of shingle, fine sand, and pumice, forming a dune-like bank 50 yards or so wide and probably as much as 10 feet above high water; the inner edge descends steeply to the mangrove swamp. This dune supports a flora of grasses and low bushes somewhat similar to that of the sand-cay.

Now when the work of the survey was in progress we were much occupied

Fig. 5. Comparison, using similar conventions, orientation, and scale, between windward portions of Low Isles and Three Isles

with the apparent divergences from the Low Isles pattern: it is easier than might be imagined to be so absorbed in superficial impressions that none of the essential form is grasped.

In Fig. 5 are drawn out the south-eastern corners of both island reefs to the same scale. In the figure they are similarly orientated and there appear such coincidences as demand a general discussion of the rampart systems.

The idea of a progressive and unstable outer rampart has already been established, but the consequences that are involved have still to be worked out. The shingle, it will be recalled, is not swept clean across the flat, nor is it thrown on to its surface haphazard. The shingle beach encircling the island is not a hurricane beach, dry at all states of the tide, but a low rampart with a fairly even surface and a regular inner limit defined by the escarpment. Occasionally a shingle tongue runs abruptly forward. I prefer the word "tongue" for these inward projections of shingle, because "spit" is a word having a different meaning in physiography. These tongues I take to be the consequence of the sea breaking through the rampart. If the shingle is piled abnormally high at some point during moderate weather, the structure may become unstable. The effect of a rough sea will be to make the wall collapse inwards, a tongue of shingle being formed as the material is driven through the breach.

The rampart moves forward over the flat, but the shingle is at present all near the edge of the reef. There is a contradiction involved in this which implies either that the ramparts are a recent feature of the reef, or that the advance of the shingle is arrested at a short distance from the reef's margin. The survey, particularly as it is displayed in Fig. 5, gives definite indications towards the latter view.

The strongly defined escarpment forming the inner limit of the inner rampart can be seen to follow the trend of the reef margin at an even distance so faithfully that it can hardly be accidental. It seems to me that in the beginning the shingle is driven forward over the flat for some distance determined by mechanical conditions, of which the level of the flat with respect to mean sea-level may be dominant. When this distance has been traversed the rampart itself, its position, shape, and extent, modifies the original conditions and defines a new set with other consequences. Either the wave action becomes powerless to carry the shingle forward any further after passing over such an extent of shingle, or, which is very much the same thing, the newly supplied detritus accumulates at the outside of this fully extended rampart to form a new and outer bank. Thus we have a sequence of advancing sheets of shingle, which are arrested when fully extended and later overtaken by a successor which, springing up outside the old one, goes forward in turn, the whole making an indefinitely repeated rhythm. The essence of this idea is the periodic movements of shingle, and as this is a notion which may be found difficult to accept it will be examined more closely.

On Low Isles the inner and outer ramparts constitute without doubt two series of shingle. If the normal working of the system was not itself responsible for the generation of a second order, then we must postulate an external agency. We might suppose the supply of shingle to be highly discontinuous so that each rampart series corresponded with a rich harvest of coral debris; but irregularities on such a scale separated by considerable intervals of time are hardly

probable, though no doubt the supply of material fluctuates. Alternatively an emergence of the reef might be presumed, such as would follow a slight lowering of the sea-level. This argument is certainly stronger and would be difficult to refute on the internal evidence alone. But it will be found unable to explain those cases where there are multiple series of shingle, and rejected when reefs other than Low Isles are brought into the discussion.

Various converging lines of evidence confirm the possibility of successive waves of shingle, and we can take to begin with the reproduction (Plate 9) of part of a vertical air photograph of a section of the rampart already somewhat extended. A newly formed outer bank can easily be seen: it is more or less continuous with the trend of the outer ramparts on either side of the salient. It is interesting to note that the shingle mangrove Avicennia, usually found only on the inner rampart, has here established itself on the outer rampart with no more protection than is given by the incipient shingle wave.

Another consideration is that if the system is periodic, we should expect different islands to show the cycle in different phases, while on the other hand, if we were examining a set of islands which had experienced a varied history of general influence, we should expect neighbouring islands to be in simultaneous stages of development. There is the possibility of the local and diverse operation of factors such as emergence, but reasons for rejecting this will be presented when we come to consider the distribution of these island reefs. I take Low Isles, Three Isles, and Hope Isles (the latter as indicated by the fragmentary survey of Fig. 5) to be in different phases rather than different stages of development, the word "phase" being used in its mathematical sense, that of the instantaneous condition of a cyclic system.

Of all the evidence the strongest is that the three measured cases show mutual numerical agreement in the limiting distance traversed by the shingle. The same interval between the low-water edge of the reef and the inner edge of the inner rampart is repeated within a few per cent. of the same value at the south-east corners of the different islands. At Low Isles the inner scarp follows the low-water contour of the reef at about 700 feet distance. At Hope Isles, where we have apparently the phase in which the outer rampart has completely overrun the inner, the single existing rampart has its inner edge at the same distance from the outside. On Three Isles the inner edge of the dune is at the same distance, as are the ridges in the honeycomb rock. Further, the inner shingle tongues (excluding the "long" tongues, which are evidently not of the same system, but including that running west-south-west into the mangroves at Low Isles) on both islands correspond within a very little in their length along the direction of travel of the shingle. This coincidence of numerical quantities makes a very strong case for supposing that these three examples of island reefs all demonstrate the operation of a single principle.

With this idea in mind and the diagram of the two south-eastern corners before us, we can make an interesting comment on the "promenade" of Three Isles. It has already been noted that the position of the inner edge of the dune corresponds closely with the inner edge of the inner rampart in the analogous position at Low Isles. I take this to mean that the dune is not an additional and incursive accumulation of coral debris between the rampart and the mangroves. It appears to have formed along and above the inner edge of the rampart in the

same way and in the same position as the bank of fine sand and shingle on Low Isles, to which attention was drawn in the figure. The two features differ certainly in size and appearance; but the appearance is determined by the vegetation (which conceals the surface completely at Three Isles), and the vegetation in its turn depends on the size of the dune, which is larger at Three Isles, as might be expected with the greater violence of the wind. At the western Hope Is. (which is about halfway between Three Isles and Low Isles) there is a sand and shingle accumulation of intermediate size (supporting a land flora, including some Pandanus trees*) which corresponds with an intermediate wind force.

If the dune is in a position as though it overlay the inner rampart, we are led to consider whether it is possible that the "promenade" is some special phase in the history of an inner rampart; whether, in fact, it is a cemented and conglomerated inner rampart now being eroded. It is at present a bank about 5 feet deep of conglomerate rock very much undercut and pitted by marine erosion. It is a feature whose form suggests a general emergence directly it is seen;† it does not however contain coral in growth positions. But since the relation of emergence to these island reefs is an important question it is as well to examine the evidence thoroughly. The promenade gives an exaggerated impression of its height. In my chain book it is noted as $5\frac{1}{2}$ feet above the platform of honeycomb rock from which it rises. Now the rock platform is very little above datum here, and is covered (as we found to our embarrassment on one occasion during the survey) at the very first of the flood. So I doubt whether the top of the promenade exceeds by more than a few inches the 7-foot level. But it will be remembered that we have established the height of the Low Isles rampart at E as $7\frac{1}{2}$ feet above datum: at E both inner and outer ramparts are much the same height and both tend to rise slightly as one works round to the north and east. Certainly the surface of the promenade has been pitted and has lost a certain amount of substance by erosion or solution or both; but the original level can be seen where it enters below the sand of the dune, where it is but slightly higher than the higher parts of the present roughened surface. So the argument that the height and position of the promenade demand elevation of the reef to explain them is at least not yet complete. But my principle objection to such an explanation of the promenade is rather different, and its full force cannot be appreciated until the third part of the paper is read. Unless relics of the old reef flat can be demonstrated in other more sheltered positions it is scarcely reasonable to put forward the promenade as an eroded form of an actual reef flat formation. But if it is claimed that it is an old rampart formation that has been elevated, then it is implied that with the reef flat at a level reasonably lower than at present, it is still possible to form ramparts, and in the same position. The argument that is to be developed later is one relating the development of ramparts to a unique level of the reef flat in respect to mean sea-level.

The basset edges of lithified conglomerate mentioned by Mr. Steers (p. 253) are by the ideas of this paper advanced one stage towards a simpler explanation than that of a presumed wholesale erosion of the reef matrix. The landward

*Fig. 5 of Mr. Steers' paper.
†Cf. Steers, p. 253.

dip (and all those I mapped showed landward dip) may be taken to represent the inner edge of some earlier rampart position, successive ridges corresponding with successive shingle invasions and small advances of the rampart. But as yet I do not realize the significance of the even distance of their occurrence from the edge of the reef.

The ideas of the shingle movements here put forward must be taken as principles to be linked up with the other ideas of the island reefs, rather than as comprehensive explanations of all the shingle features of the map. The ridges of Three Isles are claimed on the evidence of their position alone as relics of a former inner rampart; no suggestion is offered of the mechanism of the removal of the shingle of the inner rampart. But the disconnection of contemporary long shingle tongues from any outer shingle system is convincing enough to show that shingle on the flat can be removed. And in the discontinuous western extensions of the inner rampart at Low Isles there can be found evidence that under suitable circumstances the inner rampart may be concreted. The height of one such cemented part was 6·6 feet. Further surveys and examinations, including the observation of the effects of a tropical disturbance, will have to be available before the detail can be worked out.

We may make a comment about the mangroves on these islands by developing the idea of the relations between the ramparts and the mangrove swamp. The dominant tree of the swamp was stated earlier in the paper to be *Rhizophora mucronata* Lam. This mangrove belongs to a family having a highly specialized means of dispersal. The seed germinates on the parent tree and sends out a hypocotyl about a foot long. When this seedling falls it is completely equipped for immediate growth on the neighbouring substratum or for a long journey in a state of suspended animation as a floater. If a seedling fall at a time when there is sufficient water, it will, by virtue of its peculiar density distribution, float upright and be carried away by currents to continue its growth when it grounds in sufficiently sheltered water.

At Low Isles there is no reversal of the monsoon. The south-east Trade blows for nine months of the year; during the remaining three months of the year there is a rainy season of markedly different climate, but the north-west monsoon proper does not extend so far to the south. During this summer season there are spells of overcast weather, very moist and gloomy, alternating with periods of fine calm, a glassy sea, astounding visibility, and a ferocious sun blazing overhead. There are occasional periods of south-easterly weather with rain, but on the whole rampart building, erosion, and the Trade drift are at a standstill. During these summer months entire trees, felled trunks, and cut timber are carried down to the sea by the flooded rivers; while cruising in the *Magneta* during February quantities of driftwood were to be seen and invisible flotsam was struck more than once. Logs would frequently go aground on to the reef flat at Low Isles, and had to be constrained lest they came to rest on experimental corals. At this time of the year mangrove seedlings are floated out from the mainland towards the reefs.

A freshet, a torrent of flood water, can ferry out a shoal of seedlings of Rhizophora,* and it is by no means improbable that at this season the drift

*Crossland, C., "Note on the dispersal of mangrove seedlings," *Ann. Bot.*, 17, 1903, p. 267.

against the Trade* would take the seedlings to the inner side of the rampart at the south-east, so that they came to rest along its inner edge, where they would be in a favourable position to survive the Trade when it should blow home later. The ramparts are related to this colonization of the swamp not only on account of the shelter they give but also by the mechanical support they provide for the young seedling. The seedling must go aground before the roots can attempt to take hold. But the tide must not leave it lying flat on the ground. The necessary support so that it may stand vertical is readily provided by the rampart, or by a shingle tongue projecting over the flat. The shingle must be almost stationary if the seedling is going to have a chance of establishing itself securely, for a rampart advancing at its usual rate will overwhelm and kill young Rhizophora plants. This condition supports the idea that the shingle reaches a limiting distance beyond which there is only very slight progress, or none.

In the first two parts of this paper I have attempted two descriptions. First, that of the complex of reef-flat, sand-cay, boulders, and mangrove-swamp as they appear to a traveller who, voyaging up the coast of Australia from the south, sees this island for the first time as something unfamiliar and rather odd. And later, by discussing the mutual relations of the features of these islands, I attempted to give the idea of them that is in the minds of some of us who for eight months explored, examined, measured, and recorded them. Our work has separated the general query of these island reefs into two problems. The accumulation of debris on a reef flat constitutes one problem, and the formation of the flat another. Such a division is only justified by the actual results of our work on Low Isles. There is no *a priori* reason why the formation of the whole complex should not be a continuous process; and in fact it will be mentioned in the third part of the paper that in the East Indies it appears to be so. Of the work we have done, the greater part forms a beginning towards the understanding of the first problem, that of the conditions for, and the nature and distribution of, coral debris on a reef flat. The second problem, which is the story of the formation of a coral reef, has hardly been approached. Clearly our observations on other reefs than Low Isles will bear on the first problem, that of the accumulation of debris on a reef flat; in the third part of this paper I hope it will be possible to evolve a simpler and more direct statement of the nature of these island reefs as units in the great complex of the Australian Barrier System.

APPENDIX I: A Note on Early References to Low Isles and some other place-names in the text of this paper

Captain Cook, during the time he was a lieutenant in command of the *Endeavour* on that first voyage of scientific and imperial enterprise, passed Low Isles in the a.m. of 10 June (Trinity Sunday) 1770. In the entry in his Journal for that day, we find the event thus recorded: "At 11 we hauled off N., in order

*Cf. 'Australia Pilot,' vol. iv, 1st ed., 1917, p. 210.
"Caution should be exercised when passing Satellite Reef, as during the north-west or rainy season there is frequently an off-set from the land towards Trinity Opening." Satellite Reef is 8 miles south-east of Low Isles.

to get without a Small Low Island which lay about 2 leagues from the Main."* Twelve hours later he met a disaster that was all but fatal. The final entry for the same day (which concluded at noon) runs: "The Shore between Cape Grafton and the [Northernmost point of Land in Sight] forms a large but not very deep Bay, which I named Trinity Bay after the day on which it was discover'd; the North point Cape Tribulation, because here began all our Troubles." That evening, at 11 in the p.m. of June 11 by Cook's reckoning, "the Ship Struck and stuck fast" at the "S.E. edge of a reef of Coral Rocks." The story of the calamity and the recovery is familiar enough. Five miles north, and easily visible, lay two small low islands; before it was known that the *Endeavour* could be kept afloat, the utmost wishes of those on board were to run the ship ashore where they might build a vessel out of her materials to carry them to the East Indies. These islands were named Hope Islands.

The ship was eventually repaired from her own resources in the Endeavour River. Such as is left of Cooktown, where a couple of hundred people inhabit a town built for ten thousand, stands on the site. Now only the names of the public houses recall the palmy days of the goldfields and the first development of New Guinea. "Post Cineres Gloria Venit" is the inscription on the monument to Cook. While they were working on the *Endeavour* Mr. Banks, the gentleman naturalist who was later to be Sir Joseph, saw the first kangaroo seen by a white man: the word "kanguru," so widely known, was obtained from the natives of the locality.

The descriptive name Low Isles is accepted as definite by the navigators that succeeded Cook. Captain P. P. King, H.M.S. *Mermaid*, was probably the first to follow Cook; he passed the island in June 1819, forty-nine years after the *Endeavour*. The name Low Isles is written on the fair copy of his chart, apparently by King himself. His Journal contains a comment which throws a tantalizingly inadequate glimmer on the past history of the island. "At noon our latitude was 16° 28′ 48″ and three small islands were in sight ahead, which we passed to seaward of. They are laid down by Captain Cook as one island, whereas they are distinctly three, but all connected by a reef which was covered when we passed."† The suggestion that at a known time there were three islets is important geographical evidence. Unfortunately King did not, it appears, land; the sketch plan of the island on a very small scale made by the vessel while passing cannot help us. Jukes, the naturalist and geologist of H.M.S. *Fly* (Captain Blackwood), sailed past in June 1843, but fails to mention the island in his Journal.

H.M.S. *Rattlesnake*, which in July 1848, eighty years before our expedition, brought the first party of investigators to Low Isles, gives evidence from two sources, which are contradictory. The first is that of Mr. Macgillivray, surgeon and naturalist, who was accompanied by Thomas Henry Huxley as his assistant. Macgillivray's statement is definite enough: "This small group may be said to consist of three islets. One is low, sandy and well wooded, about 300 yards in diameter, and is situated at the north-west extremity of a horse-shoe reef, with its concavity to leeward; the other two may be looked upon as merely groves of

*"Captain Cook's Journal," edited by Admiral Wharton, 1898, p. 274.

†King, P. P., 'Narrative of a Survey of Intertropical Australia,' 2 vols. London, 1827. Vol. i, p. 207.

mangroves on the reef."* Captain Owen Stanley (a name not unfamiliar to geographers) was in command of the *Rattlesnake;* the following is transcribed from the manuscript Sailing Directions compiled by Stanley:† "Low Isles are properly speaking only two in number: the larger situated near the West end of a coral reef is about 300 yards in circumference, low, sandy and well wooded; . . . the other island is composed of one or two clumps of mangroves growing near the eastern edge of the reef." The party spent three or four days at the island, the naval officers making a rough survey of the island in addition to their triangulation work for the general chart, and the naturalists making their collections. Low Isles provides difficulties even in its simplest definitions.

The interpretation of the scanty evidence is largely a matter of individual opinion. In the Admiralty collection of sketches and drawings there is an aerial perspective of Low Isles with Snapper Island and the mainland in the background. It is impossible to be certain of the artist, but a reduction of the possibilities makes me think that it was probably drawn by Stanley. It shows two main areas of mangroves in contact or narrowly separated, the first occupying the position of the north of the present mangrove swamp, and the second due south, probably occupying part of the present mangrove park and in contact with the two large isolated relics of inner rampart between C and E beacons on my map; these shingle banks are still populated by a few ancient and battered Rhizophora trees. This supposition agrees with the plan of Low Isles published by the Admiralty in 1855 from surveys by the *Rattlesnake*.

In 1905 H.M.S. *Penguin* in the ordinary course of survey duties made a plan of Low Isles on a scale of 4 inches to 1 mile. The datum then established was adopted for use in our work: the surface features are not described in sufficient detail to enable any significant inferences to be drawn so soon after the original survey.

In the preparation of this note I was given much assistance by Mr. Townsend of the British Museum library at South Kensington. The Hydrographer, Admiral Douglas, and Commander Jackson of the Chart branch of the Admiralty kindly supplied information and facilities. I am grateful for Mr. Tandy's suggestions and for a comprehensive bibliography prepared by Mr. Steers.

*Macgillivray, J., 'Narrative of a voyage of H.M.S. *Rattlesnake*, 1846–50.' 2 vols. London, 1852. Vol. i, p. 101.

‡Property of the Admiralty.

(*To be continued*)

LAKE EYRE, SOUTH AUSTRALIA

C. T. MADIGAN

Introduction

THE Lake Eyre Basin, in Northern South Australia, is an area of great physiographical and geological interest. It is the focus of the great Australian inland drainage system bounded by the Macdonnell Ranges in Central Australia on the north-west, and by the Queensland coastal ranges on the north-east, a watershed of 450,000 square miles. It is also the driest and most desert area in Australia, being ringed by the 5-inch isohyet. Though mighty rivers begin their long journey to Lake Eyre in rainy seasons, yet their courses through their flood plains in South Australia are indefinite over distances measured in hundreds of miles and they have countless swamps and minor lakes to fill on the way, so that the amount of water that ever reaches the lake is still a matter of doubt.

It is indeed an inhospitable region, visited only by occasional stockmen mustering cattle during good seasons, and even their activities have ceased during the past seven years of drought. At the present cattle, and even camels, have disappeared from the country. There is still no consecutive story available of conditions at the lake throughout a year, or even after some of the rivers have been discharging their occasional immense floods into that great parched and saline flat.

The lake covers 4000 square miles. The north lake measures 110 miles across in its longest direction, and the south lake, connected to it by a narrow channel, 40 miles. The lakes lie roughly between latitude 28° and 29° 30′ S., and the meridian of 137° E. passes through them. The whole region has been held under pastoral leases, but there has never been a homestead within 20 miles of the north lake, and the few habitations in the area are now mostly abandoned. The latest to go was Muloorina, for twenty years a Government camel depot. The last of the starving camels were destroyed last year.

Accounts of the lake by explorers and stockmen differ widely. It has been represented as a genuine lake, with deep waters and waves, the source of the fish found after floods hundreds of miles up the usually dry courses of the rivers (these fresh-water fish of course have no connection with the lake), and on the other hand as a dreary burning waste. There are also many interesting legends about the lake, mainly founded on the traditions of the almost extinct aboriginals of the area. The reason for the remarkable differences of opinion about it is that the observers have seen its shores at points possibly a hundred miles apart, near rivers in flood or far from them, in wet seasons or in drought, and probably not more than once in any year, if not but once in their lives. The distances are so great, travel so slow owing to the nature of the sandhill country rendering the camel the only means of transport, and the necessity so infrequent and inducements so few to the scattered stockmen in the area to visit the lakes, that the distribution of water after floods, and the depth, and the time the water lasts, are still only matters of conjecture. This desolate region remains one of the few areas still unconquered by the motor car. There are no roads or even tracks to the north lake. Owing to the ever-present mirage, one can never see

more than a couple of miles out on to these lakes, though of course the distance seems much greater. Only the very inexperienced would mistake the mirage for water, though the appearance is invariably that of a vast sheet beginning a mile or two from the shore.

An excellent summary of previous explorations in the area, and a very complete list of references to the literature, is given in Gregory's 'Dead Heart of Australia.' It will be of interest here to mention only the salient points in the history of the exploration of the Lake Eyre Basin.

The great pioneer Eyre first reached the southern shores of the lake which later bore his name, in 1840, and stood at the point called Eyre's Lookout. Exactly eighty-nine years after him, in the same month, my companions and I flew on north over this point to the centre of the lake, Eyre's formidable barrier to the interior having vanished before the march of human progress. Eyre believed the lake to be part of a great horseshoe lake including Lakes Torrens, Eyre, Gregory, Blanche, Callabonna, and Frome, as we now know them. He thought that this horseshoe barred the way to Central Australia in that region. Babbage in 1858 first made known the separation of Lake Torrens from Lake Eyre, and the eastern side of the horseshoe was broken up by Parry, Stuckey, and A. C. Gregory.

Up till 1860 the Lake Eyre Basin was considered to be a barren, waterless, and dangerous desert. However, in that year McKinlay, on one of the Burke and Wills Relief Expeditions, had the fortune to travel in one of the rare good seasons and described the country east of Lake Eyre as a series of lakes and meadows. His reports led to the occupation of the country for cattle raising. Its history since has been a series of periods of promise and hope followed by bitter failure and ruin. It is a tantalizing, fascinating region. In its good seasons its hundreds of miles of knee-deep grasses lure men to their destruction. Once they have come under the spell of its vast spaces they cannot leave it. The waving grassy plains change to a burning stony desert, the stock cease breeding and gradually die out, the sand drifts over the pitiful fences and stockyards no longer used, its yellow, glaring ridges slowly approach and engulf the homestead, and yet men hang on. Month after month the brazen sky is watched. Heavy cloud forms, to clear away again. Years pass, but some day the cooling torrents will fall, the dry watercourses will become swirling maelstroms, and the country will wave with grass again. These periods of flood come at periods of something like ten to twelve years. The Diamantina country was flooded in 1917 and the last drought broke in December 1929, just after the completion of the two journeys to be described here.

Warburton explored the northern end of the lake in 1866. His work formed the basis of the map produced in 1872–3 by J. W. Lewis, who traversed the whole of the lake except the south-western portion, and much of the country to the east. Lewis described his journeys and the country in great detail. His journal with map is available as Parliamentary Paper, South Australia, 1875, No. 114. Warburton, in his gloomy and fearful account, reported that no water was to be seen, and spoke of the cracked and rotten nature of the northern shores. Lewis reported that his party went out on the lake for 2 or 3 miles in several places, and used powerful glasses from the tops of the highest sandhills, but never saw a drop of water. Referring to the lake he said, "I sincerely hope

I may never see it again." He describes in detail a venture of his own for 200 yards out on to the lake from the middle of the western side. He came upon a salt crust 3 inches thick and broke through this with a stick, disclosing a stinking mud below, and causing the salt to crack all round. He escaped by rolling away towards the shore. He is the only writer or observer who has so far mentioned a salt crust on Lake Eyre. He writes, "I did not feel inclined to try again, so quietly walked back to my camp, leaving the nature and depth of the bottom at this point of the lake a mystery." One of his parties, in his absence, walked 7 miles in from the north end, and ran a line of levels, finding that there was a fall of 2½ feet in the 7 miles. They tried to sink a hole at the end of the walk, "but found it too soft." There is no description of the lake surface, or explanation of how it was that the surface was firm enough to walk on, yet a hole could not be sunk. There is also no mention of salt at that end. The north end is the delta of the Neales, Macumba, and Diamantina rivers (called The Warburton near the lake), and probably there is no salt there in the first 7 or 10 miles.

Next we come to Professor J. W. Gregory's expedition when, with a party of students from Melbourne University, he made an excursion from Marree round the eastern and northern sides of the lake in the summer of 1901. His delightful book, 'The Dead Heart of Australia,' contains a summary of all the available knowledge of the area up to that date, and nothing has been added during the past twenty-eight years except the short note by Mr. Halligan. By Gregory's time a trigonometrical survey had been run round three sides of the lake (the northern end is a barren, sandy, and featureless waste and has not been "trigged") and carried up to the Central Australian boundary on the west, in the neighbourhood of the telegraph line, and now of the railway, and north-east to the corner of Queensland. Gregory's object was chiefly the study of the Australian desert and the search for Pleistocene fossil remains, and he paid little attention to the lake itself, but travelled mainly in the country to the east of it. The party only sighted the lake surface once, and found nothing to interest them there, or perhaps one should rather say there was so much more to interest them away from its shores that they paid little attention to its surface. They made "a short cruise" out on to the lake on its eastern side, just south of the entrance of the Cooper, and "could have gone much further." There was no description of the surface, but apparently no salt was seen or it would surely have been mentioned. There was no mention either of bog of any kind.

Finally came a notable effort by Mr. G. H. Halligan in 1922 to investigate what lay within the borders of the lake. Its shores had by now been mapped in as great detail as will probably ever be necessary, the animal and plant life in the area had been collected and discussed, possibly not yet completely, the geology had received considerable attention, chiefly from the South Australian Government Geologists H. Y. L. Brown, L. K. Ward, and R. Lockhart Jack, and the pastoral possibilities and impossibilities were well understood by the big pastoral companies and their smaller and less fortunate brethren the private lessees.

The only remaining major problems were concerned with the lake bed itself. It was not even known what proportion, if any, of the lake was covered with water, or how the water varied with the seasons and rainfall. It was generally

considered that there was always some water in parts of the lake, from accounts by aboriginals of collecting birds' eggs. The world interest in the alkalis had also directed attention to these giant saltpans in South Australia. The South Australian Government and also certain chemical firms had investigated several

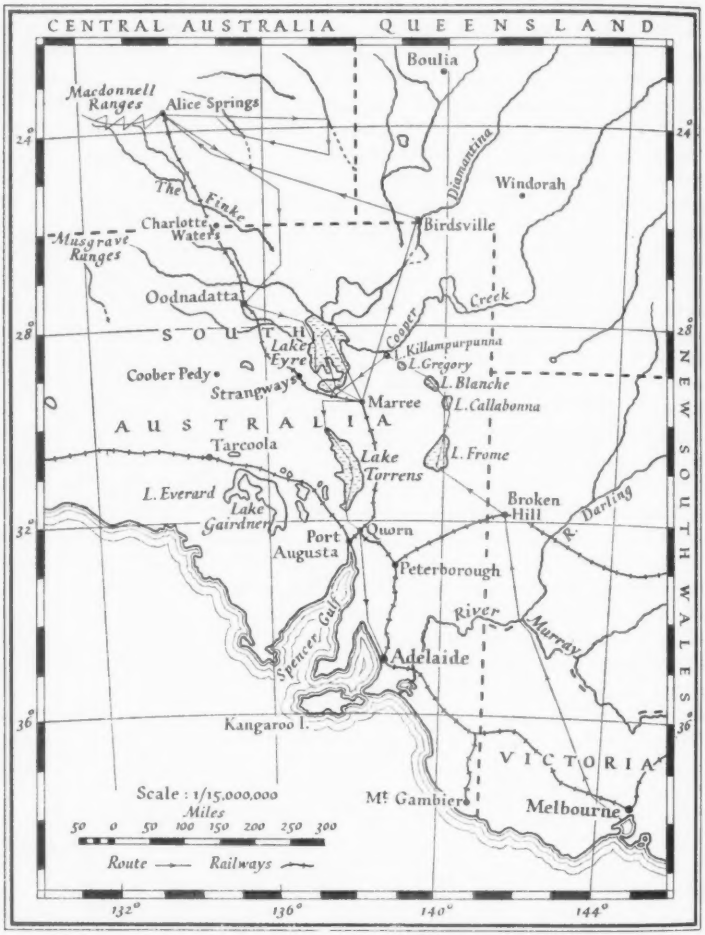

Fig. 1. The routes of the Aerial Reconnaissance, August 1929

of the nearer lakes, but so far the greatest lake of all remained untouched. The common salt and gypsum industries, carried on in lower South Australia, were already of considerable and growing importance. There were also legends of islands within the lake, possibly inhabited, and there were possibilities of the presence of fauna on the islands unknown on the mainland, descended from the

great Pleistocene mammalian fauna of Central Australia, whose remains are plentifully exposed on the surface in the deltas of the Diamantina and Cooper.

Thus Mr. Halligan formulated a scheme for a hydrographic survey of the lake. Early in 1922 he flew down the western margin of the lake from north to south, at a height of 8000 feet, in Defence Department aeroplanes. At that time it was considered unsafe by the pilots to fly at a lower altitude in practically unknown country. Halligan reported that the lake was about one-third full of water, and from the colour he estimated the depth at from 4 to 6 fathoms. He returned four months later with a specially designed boat, but like Lewis, who had been instructed fifty years before by the Government to get a boat out on the lake, he found no water when he reached the shores on foot, and the vision of a great adventure came to a disappointing end. Thus the mystery of the presence or absence of water was intensified. Halligan saw no water in Lake Torrens. As it was after a wet season, it is possible that there was water in Lake Eyre, but I feel sure that the depth would have been much less than his party estimated. They did not fly over the supposed water at any point, and considering the height, a mistake could easily have been made. The pilots agreed that it was water.

The evaporation is at the rate of 100 inches per year. The catchment area is some 450,000 square miles, and the average rainfall over that area about 10 inches. Assuming the run-off at 5 per cent., a high figure considering the aridity and sandy nature of the catchment (it is probably nearer 1 per cent.), the annual addition to the lake, with its area of 4000 square miles, would be 56 inches. This amount can rarely be realized, as for years on end the big rivers from Queensland never discharge into the lake at all. Thus the evaporation far exceeds the most generous figure for intake, and permanent water might have been considered most unlikely, unless the lake-bed were extremely deep (the southern shores are 39 feet below sea-level) or the lake were fed from an artesian source. It lies within the Great Artesian Basin.

Halligan published accounts of his journeys in the *Proceedings* of the Royal Geographical Society of Australasia, South Australian Branch, vol. xxiii, Session 1921–22, and in the *Report* of the Australasian Association for the Advancement of Science, vol. 16, 1923.

The Aerial Reconnaissance

In August 1929, through the support of the Royal Geographical Society of Australasia, South Australian Branch, and the courtesy of the Minister for Defence and the Royal Australian Air Force, I made an aerial reconnaissance into Central Australia. The main objective was the exploration of an area of some 30,000 square miles of unknown country in the south-east corner of the State of Central Australia, and in South Australia north of Lake Eyre, country which had never been crossed by white men, nor by aboriginals as far as was known. An important secondary consideration was the aerial investigation of Eyre's horseshoe of lakes. A general account of the flight appears in the *Proceedings* of the Royal Geographical Society of Australasia, South Australian Branch, vol. xxx, Session 1928–9, with no detail concerning the lakes, which were left for fuller treatment after investigation on the ground.

By now aerial equipment was much improved, and the two Westland Wapiti

machines spent four flying hours over Lake Eyre alone, coming down so low as to taxi on the surface at the centre of the lake.

The course of the flights is shown on the map, Fig. 1. On the flight from Broken Hill to Marree, Lakes Frome, Callabonna, Blanche, Gregory, and Killampurpunna were flown over. It must be remembered that this was at what proved to be the close of seven years' drought, for heavy rains came at the end of the year. The lakes could probably not have been seen under drier conditions. There was not a drop of water in any of them, including Eyre and Torrens. There was a great similarity between all the lake beds. Their surfaces were mainly pink, featureless expanses, with occasional irregular areas and patches of white salt. Oblique photographs showed a patchy appearance, but those nearly vertical in most cases showed nothing at all. Plate 2 shows the southern margin of Lake Frome. The light areas are salt, the dark, clay or pink salt. White salt along the margin was typical.

In Lake Frome there were several long narrow islands with a meridional trend, and some long sandhills supporting bushes, probably canegrass. The islands were flat-topped, and a note was made in the air that they were residual and not formed of drift, the latter a suggestion of Halligan's in the case of Lake Eyre. Further investigations showed that all the great sandhills of the area took the direction of the prevailing wind, and after the gypsum cliffs and islands of Lake Eyre were examined on the ground it was concluded that these islands were of sand and gypsum, wind formed. Plate 1 shows one such. This picture is a good example of the typical patchy appearance of the surfaces of Lakes Frome and Torrens. The two lakes probably receive water at least once annually, unlike Eyre, and white salt is left on the surface where the last sheets of water, blown about by the wind, evaporate. The older surfaces and salt crusts are pink from sand and dust. There were white areas opposite nearly all the creek and river mouths on all lakes, proving this point. On each occasion when we came down to 100 feet on Lake Frome the surface was logged as pink clay. Later investigations on Lake Eyre indicate that it was a pink salt crust. In most places it was tessellated with what appeared to be cracks. A patch of water, recognized as a mound spring, was seen in Lake Callabonna, and photographed.

Both Lakes Callabonna and Blanche were much drifted over with sand. Small dunes with a north-north-east trend, and drifts formed by bushes, were very common on them. The country on the north-east side of these lakes is a mass of sandhills. It was very difficult to determine the shores of the lakes from the air, and at times we were puzzled to know whether we were over them or not. After passing over Lake Blanche we got a little "bushed" and passed to the north of Lake Gregory which was not in fact differentiated from the surrounding country at all, though well within sight. Our map position was not again located till Lake Killampurpunna, on the Cooper, was reached. There were no sand drifts on it. The Cooper was here but a broad belt of scattered trees.

On the return from the northern reconnaissance attention was concentrated on Lake Eyre. The first flight over it was on the journey from Oodnadatta to Marree. The lake was approached from the north-west end. A little water was seen in the Koorakarina Creek and also in a pool where Barlow Creek enters the

Neales river, practically on the lake margin. There had been a little rain in the Oodnadatta region during the month (August 1929).

The courses are shown on the map, Fig. 2. From the Koorakarina Creek we turned south-east, thinking we were on the lake. Its margin was very difficult to determine from the air at any point. Its surface was of the same pink colour as the sandy wastes around it, the relief of the shores is small, and all the herbage on the land was dead, except for the gums higher up the creeks, which always mark out their courses most clearly. We saw occasional dead bushes, and a few mulga, on a level sandy flat which we took for the lake floor. We were here really flying over the deltas of the creeks flowing from the low tableland to the west. At the next turn south in the course we discovered our error, recognizing the true lake surface with here a margin of white salt. We found that there was no vegetation of any sort inside the lake shores. Some white areas of salt were seen at these creek mouths, really in their deltas rather than in the lake proper. The little cape in the middle of the west side was recognized, and here we turned east for the centre of the lake, passing over a featureless pink plain, most of the surface appearing cracked, with markings like a baked apple. Close to the western shore a darker area ran north from a mile or so north of our course. It appeared to be a depression in the lake-bed, and I believe was the broad course of water from the Macumba in the north towards the southern end of the lake. Photographs from 2000 feet mainly showed nothing unless the shadow of the plane came in the field.

I had asked the Air Force to supply some bombs to be dropped in the lake centre to test the nature of the surface, whether mud, earth, or salt. The aeroplanes were fitted for bombing, but I withdrew my request when Air Commodore Williams pointed out the difficulty and danger of carrying bombs for such a long distance. They were not to be used until the return journey. The light bombs would not have been effective and the heavy ones would have added rather much to our load. We were carrying three men instead of two, and considerable gear. As an alternative, I designed some spears to drop. The first two, made for me by the Commonwealth Railway workshop at Alice Springs, consisted of 6-foot wooden shafts let into 2-foot lengths of 2-inch iron piping, which was cut out and hammered into a fine point. Two standard-coloured message bags were attached as streamers. My own opinion was that these bag streamers could not have been better designed for natural protective colouring for use in this country, a view hotly and loyally contested by the pilots. I dropped these two spears in the centre from a height of 1000 feet, through the floor of the fusilage. It was hard to follow their flight, but they seemed suddenly to disappear. We were unable to pick them out on the surface. I thought they had sunk out of sight, but now doubt it very much. We now returned to the western shore, a little south of our course in towards the centre of the lake, and then turned south.

Just north of the Douglas Creek entrance, and about 5 miles from the shore, we saw below us what at first appeared to be two post-and-rail fences, perfectly straight lines, crossing each other, half a mile or so long, a most puzzling sight. They had a similar loop at the shoreward end of each. A couple of dives down on to them showed them to be the tracks of two animals, probably camels, sunk about 1 foot into mud, though appearing dry then. The dragging of the

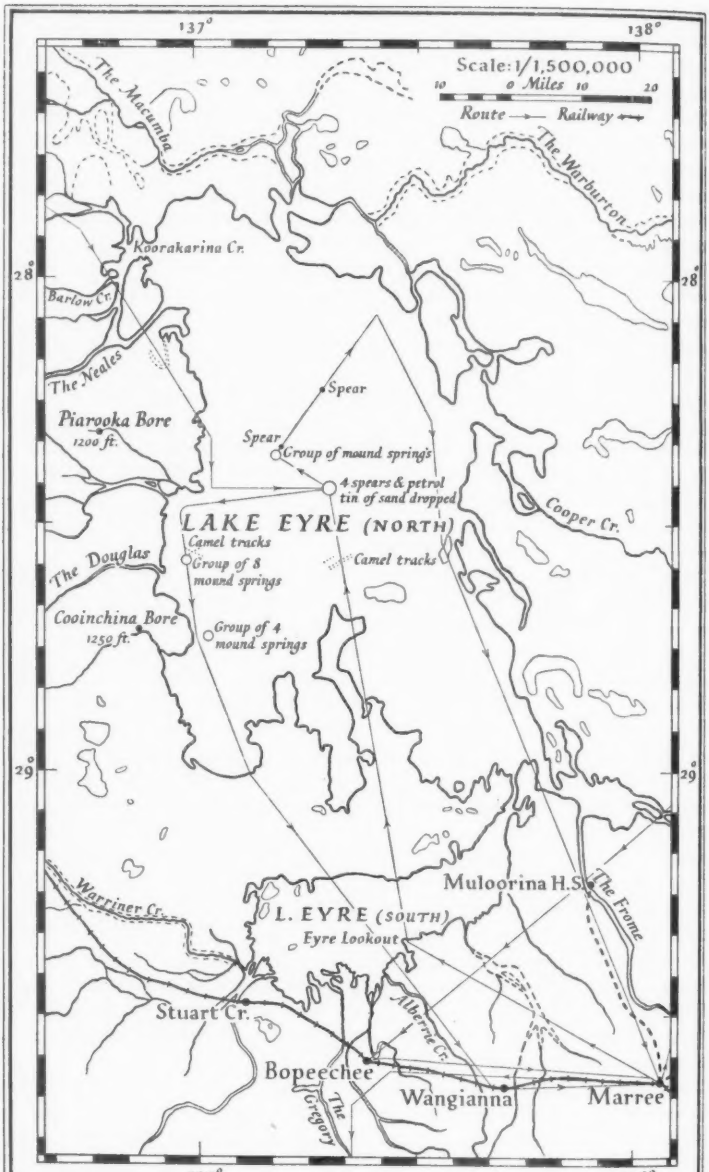

Fig. 2. The aerial flights over Lake Eyre

feet on the surface between the footmarks made the rails, and the pairs of holes merged into one post at a distance. The tracks had exactly the appearance of the shadow of a fence of two rails. Another dive was made on to one of the loops at the end, where I was sure we should see a dead animal, but these were found to be where the animals had lain down when it became too boggy and then turned and retraced their steps exactly. The tracks came in from the north-east, not from the shore. This was our first real intimation of the solid nature of the surface, the fact that animals could wander about on the lake.

Immediately afterwards we saw the reason for the attempt of these animals to make in that direction. Below us was a group of mound springs, eight distinct large white patches in the pink surface, each with a dark pool in the centre. Plate 3 shows a general view of some of them, from 2000 feet. These were sighted by Halligan, who located them off the mouth of the Douglas Creek, with which we agreed. Doubt had been expressed as to these being real mound springs connected with the Artesian Basin, but I was quite convinced, on comparison with other springs seen from the ground. We flew low over them and found them to consist of low mounds rising to only some 6 to 10 feet above the general level of the lake floor, as is the case with Hergott Springs, near Marree. There was a narrow lip standing up about 1 foot round the pool of water, which was clear and blue and up to 20 feet across. The mounds were up to 100 feet across, with rough and crusted sides. There were eight conspicuous white areas, as seen by Halligan from the distance, but closer inspection showed some of these areas to contain many small springs, as can be seen in Plate 4, which also shows the tessellated nature of the salt crust on the lake surface. The springs were possibly in a slightly lower area, as the camel tracks were boggy only in their immediate neighbourhood. There was nothing to indicate whether the ground was still boggy, but from later investigations I think it was not. The animals had come towards water from the direction of the centre of the lake, but had been forced to return. Twelve miles farther south, and a few miles in from the shore, four more mound springs were passed.

Geological sections by L. Keith Ward across the Great Australian Artesian Basin, which include portions of Lake Eyre, based on bore logs, indicate that the depth of the water-bearing sands at the western edge of the lake should be about 1500 feet (see Report of the Third Interstate Conference on Artesian Water, Adelaide, 1921). Piarooka Bore, 14 miles from the western margin, struck water at 1200 feet, and Cooinchina, 5 miles west, at 1250 feet. The south-western edge of the Artesian Basin lies just south of the railway line on the map, Fig. 2. The railway marks out an almost continuous line of mound springs, which have been recognized right to the edge of Lake Eyre South, north of Bopeechee, but mound springs do not appear to approach nearer than 30 miles from the western side of the north lake. However, the recognized mound springs of Lake Callabonna occupy a precisely similar position as regards the edge of the basin. The same authority gives the depth of the water-bearing sands there as 2000 feet, and bores in the neighbourhood have depths of those dimensions. The geology of the area is fully discussed by R. Lockhart Jack in Bulletin No. 14 of the Geological Survey of South Australia. Mr. Jack informs me that he postulates faults for the escape of waters in the Callabonna region, and the same could well apply to the western side of Lake Eyre. The

sections do not indicate any large displacement in the region, which appears to be an area of subsidence, with water escaping up fault fractures near its margin.

As the south-western edge of the lake was approached, small dunes were noted on its surface. The region between the lakes was logged as very desolate sandy country, without conspicuous sandhills. The latter were low and far apart, with a trend of N. 15° E. Lake Eyre South presented the same pink featureless appearance as the main lake. A bore stream 3 miles long ran from the Charles Angus bore to the margin of Lake Eyre South, where it faded away.

A telegram to the Air Board resulted in petrol being supplied for a further flight over Lake Eyre, so that a more extensive flight from Marree was planned. As I was still doubtful whether my first two spears had disappeared in the lake, I had four more made in Marree, consisting of 12-inch lengths of 3-inch water piping brought to a blunt point and fitted with 6-foot wooden shafts, to which were attached 24-foot strips of white calico 6 inches wide. On two of these I screwed 7-inch flanges, the flanges being at the top of the 12-inch lengths of pipe; on one was a 6-inch flange; and one was without a flange. I would have used longer shafts, but they would have been very awkward to stow, and also to get through the bottom of the plane. A little practice with the plane on the ground made the operation very simple. The streamers were of such great length in order to give them a chance of showing on the surface if the spears themselves sank out of sight. I also arranged for the other machine to take a petrol tin full of sand to be dropped.

A course was made for Eyre's Lookout, in the centre of the southern shore of Lake Eyre South, and a photograph was taken from this point of the scene viewed by Eyre in August eighty-nine years before. A northerly course was then taken across the South Lake and up the peninsula in the North Lake. The courses of the flights are seen on Fig. 2. Lake Eyre South presented the same pink featureless and waterless appearance as on the other crossing. The country between the lakes was barren, with a few sandhills trending N. 15° E., and some scattered mulga (an acacia) and needle-bush (a hakea). The northern shore of the South Lake is considerably more indented than is indicated on the map, and I made the western end a couple of miles farther south than is shown. About halfway up the peninsula, when the lake-bed below and to the east was more clearly seen, we observed on the surface what appeared to be little crescent-shaped mounds 30 or 40 feet long, and then the surface became tessellated with ridges. It was thought that they might be sand dunes. Their nature was fully explained during the ground expedition. Plate 5, from 2000 feet, shows this surface well.

When the end of the peninsula was passed, the surface became an even pink again. Ten miles off the end two camel tracks coming from the north-east were passed. The footprints were clear, as on a dry soil surface, not deeply sunken in. Little ridges on the surface stood out clearly again. Another pad was seen immediately afterwards a little to the west of our course. These animals had doubled back near where we met their tracks, indicating possibly that it had been more boggy to the south-west. After passing the camel tracks, the surface became featureless and pink, without even the tessellation. It appeared to have surface drift sand on it, and faint east–west lines were noted resembling thin patches of drift sand. At the centre the first spear, with flange, was dropped

from 900 feet. Its flight was easily followed, and it stood 4 feet out of the ground with its mass of calico beside it.

I then signalled the other plane to let go the petrol tin of sand, which weighed about 60 lbs. This burst when it struck the surface, making a small hole from which radiated splashes of sand. The results of this experiment, the presence of the camel pads, and the small penetration of the spear, in spite of its flange, convinced us that towards the centre at least the lake had a very solid surface, and, becoming emboldened, each plane glided down and struck the surface with the landing wheels while travelling at high speed. Dust was thrown up, and a very well-defined track was left. A safe landing could have been made, and one was sorely tempted to try it, against an agreement with the Air Force not to attempt any landings except on prepared landing-grounds. This surface was undoubtedly what is known in the country as "bull dust," which will be described in the account of the ground expedition. It might have been difficult to attain sufficient speed to rise if we had landed in that spot. A second spear was then dropped, without flange, from 1100 feet and it appeared to stand at least 3 feet out of the lake surface.

Half an hour had now been spent in the vicinity of the centre of the lake. Owing to the low shores being invisible, and there being no reference point on the pink expanse below, it was difficult to maintain any exact position, and subsequent plotting showed that we had drifted north-west during our manœuvres. At this moment we suddenly noticed mound springs below, and wrongly assumed they were those seen first on the former flight. Little time was spent on them. We made one descent close on to the largest, which I photographed. I noted that there were radial lines of flow of water from the "crater," and that the thin wall-like margin noted before round the pools of water was absent. The surface was here tessellated again, and a third spear was dropped just north of the mound springs, from 700 feet. It remained standing in the lake.

A north-east course was then set for the opposite shore. On the way, about 12 miles north of the centre of the lake, the last spear, without flange and sharply pointed, was dropped from 800 feet. It stood 3 feet out of the surface. As before a photograph was taken in which the shadow of the spear and the streamer are clearly visible. The surface in this picture has a "rice-grain" appearance which was typical of about half of the total area of the lake. It indicates bull-dust.

The return to Marree was made via the eastern shore of the lake. This seemed to be very gently shelving, with less definite banks than the southern and western sides. This is typical of all the South Australian lakes. Their eastern sides show gentle curves and low flat shores, while the western sides have definite banks and more rugged and indented outline. The explanation is that the prevailing winds are approximately south-east, so that sand and drift smooth out and keep shallow the eastern shores, while leaving the western bare and more like a shore-line under the influence of marine erosion.

There were many wide bays on the eastern side, in the flood plains of the Warburton (Lower Diamantina) and Cooper. These, when the rivers had access to them, had dark clay floors, in contrast with which the sandy country around appeared white, particularly in photographs. A photograph of the mouth of the Cooper looked like ice-floes in the dark sea. There were streaks of

sand too on the lake surface. Due east of the peninsula the lake surface was noted to be tessellated again, very conspicuously. This is shown in Plate 6, taken from 200 feet. This salt crust, as it was afterwards found to be, continued to the southern margin of the lake. The well-wooded Frome river was very conspicuous.

This completed the flying over the lake. There was no water in it, and its surface was proved to be firm, from the tracks of animals and the dropping of the spears. For further investigation a ground expedition was indicated.

Lake Torrens was flown over on the return to Quorn and thence to Adelaide. On the way the country between Lake Eyre South and the north end of Lake Torrens was examined. The divide is very low, with a flat claypan area, about 4 miles across, in the centre, and watercourses trending north and south towards each lake, away from this area, the northerly one being dignified by the name of the Gregory. There is a broad low area between the lakes, but no definite channel remains. We flew right down the whole length of Lake Torrens, over the centre. Its general features were the same as those of all the other lakes. The surface was more patchy, with more areas of white superficial salt, and there were no sand dunes on it, as there were on all the others. Water was seen in the Willochra Creek, but absolutely no water in the lake itself. Another point in common with all the lakes is that there were no signs of watercourses within the lake margins. The water probably moves about in sheets with the wind—indeed, this is vouched for by many observers—hence the patches of salt where the final evaporation takes place. The surface of the lake was mottled in areas of brown, chocolate, and cream.

One or two small sandy islands were seen at the north end, towards the west side, and at least two springs near the southern end. The springs had somewhat the appearance of the mound springs in Lake Eyre, but were less circular in plan, were not built up at all, and were surrounded by much larger white saltpan areas. The two chief springs were about midway between the shores, and 24 and 27 miles respectively north of the mouth of the Willochra Creek. There were many tracks near the springs, some leading to them, so the water was evidently potable. Twenty miles north of the Willochra Creek one well-worn pad appeared to cross the lake. Tracks of animals were also seen up to 40 miles from the northern end.

The Ground Expedition

The aerial observations thus gave strong grounds for believing that Lake Eyre could be investigated on foot. The Mines Department of South Australia had already carried out fairly extensive investigations on some of the nearer lakes, to discover their gypsum and alkali possibilities, and all the available information about them, together with his original work, is published as Bulletin No. 8 of the Geological Survey of South Australia by R. Lockhart Jack, entitled 'The Salt and Gypsum Resources of South Australia.' The Mines Department and Geological Survey were much interested in the great lake, and gave kind support to my project to take a motor car up to the lake. Through the courtesy of this department and the Engineer-in-Chief's Department, the loan was arranged of an old motor truck, which nevertheless was in good mechanical order, and two men stationed at Marree, on the railway,

Phot. C. T. Madigan

1. Dune-like island in the centre of Lake Frome

Phot. C. T. Madigan

2. The southern end of Lake Frome

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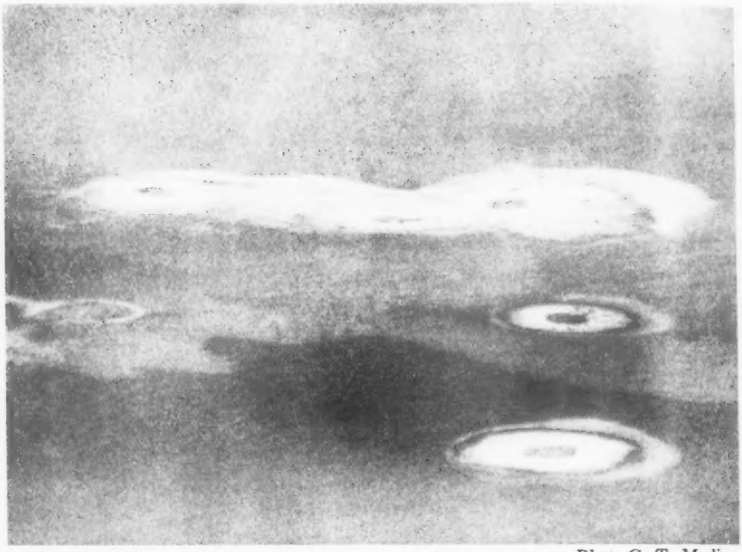
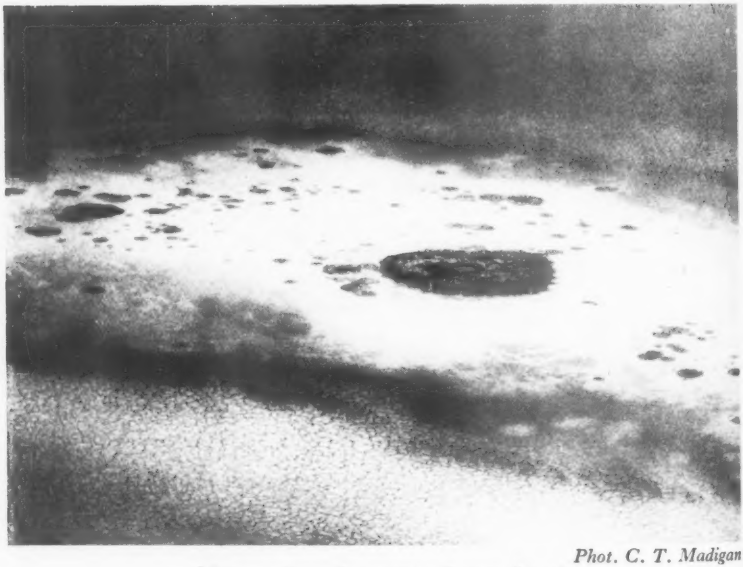


Phot. C. T. Madigan

3. Mound springs in Lake Eyre North



Phot. C. T. Madigan

4. Nearer view of a group of mound springs

50 miles from the North Lake. Owing to University duties, and also in order to keep expenses at a minimum, it was only proposed to spend a week away from Marree. If it was possible to get the car on the lake I hoped to get all over it in that time. Professor J. A. Prescott, of the Waite Agricultural Research Institute, who was specially interested in soils and was anxious to see the arid interior, accompanied me, with Mr. Charles Kunoth and his son Charles from the Engineer-in-Chief's Department, Marree, as assistants.

Before leaving I was inundated with warnings that the surface was most treacherous, that a thin crust covered a slurry that would engulf man or beast, that we should be sunk without trace, that anyway it was impossible to approach the lake in a motor car on account of the sandhills. This last was a true difficulty, already anticipated, but by going north from Marree along the Frome river we could traverse the least sandy region and also travel more or less parallel to the sand ridges, which in that region proved to be really gypsum hills partially covered with a veneer of sand, which is blown off in patches exposing a very hard surface. So old Muloorina Station was chosen as a jumping-off place, where there is an excellent well, the nearest fresh water to the lake, from which it is 20 miles distant in a direct line. No vehicle had gone out to the lake from there before, and we had to find a track. We started out with 100 gallons of water in drums, petrol, and ample provisions for a week. A dump was made 16 miles out, the first day, and camp pitched on a bare patch in the sand (or gypsum) hills near the neck connecting the north and south lakes. The courses are marked on the map, Fig. 3. Next day the remainder of the stores was relayed to this camp.

The country from Muloorina Station to the lake is fairly flat, but is crossed by a few large sand and gypsum hills up to 100 feet high, trending N. 30° E. The sandhills are closer together near the lake. All vegetation was dead except a few needle bushes. The saltbush, once thick hereabouts, was represented by brambly butts round which the drift sand had piled in mounds up to 3 feet high. It was these mounds which made the going so difficult, rather than the sandhills, which had only a veneer of sand, as mentioned above. On the way a narrow dry lake, one not before marked on the maps, was encountered. It was about 300 yards wide, and after inspection we took the lorry across it. Its surface was typical "bull dust," that is, loose sand with a pie-crust surface, due to the cementing of the sand grains by deposition of salts from the evaporation of water at the surface. The sand was some 3 to 6 inches deep, and below was damp clay full of gypsum crystals. The surface was decorated with lines and rosettes of gypsum crystals, some of the sheets of gypsum being several feet across and an inch or so thick. In the older formations (Eyrian series) in the lake area, at higher levels, there are beds of gypsum of almost unlimited extent (known locally as copi, a native name). Huge sheets weathered out of these formations lie about, and on one occasion, on the flight from Oodnadatta to the lake, the sunlight glinting off these sheets made us think at first that they were pools of water. The motor truck made heavy weather of travelling over this surface. It sank down an inch or two in spite of loosely inflated balloon tyres, but did not reach the damp clay except on occasion. When it did, restarting was difficult, and lengths of iron troughing had to be placed beneath the rear wheels. This surface is mentioned here as it was found to be typical of the

great lake margin. We looked on the successful crossing of this small lake as a good augury for success later. Another 6 miles from the camp brought us in the evening to the top of the last sandhill, which ran parallel to the lakeside, and before us, 50 feet below, lay the grey surface of the lake-bed, extending to the horizon. This point was between the mouth of the Frome and the connecting neck, and somewhat west of the point reached by Halligan with camels, from which he realized that his boat was useless.

We had brought our truck to the lake. The next thing to find out was whether

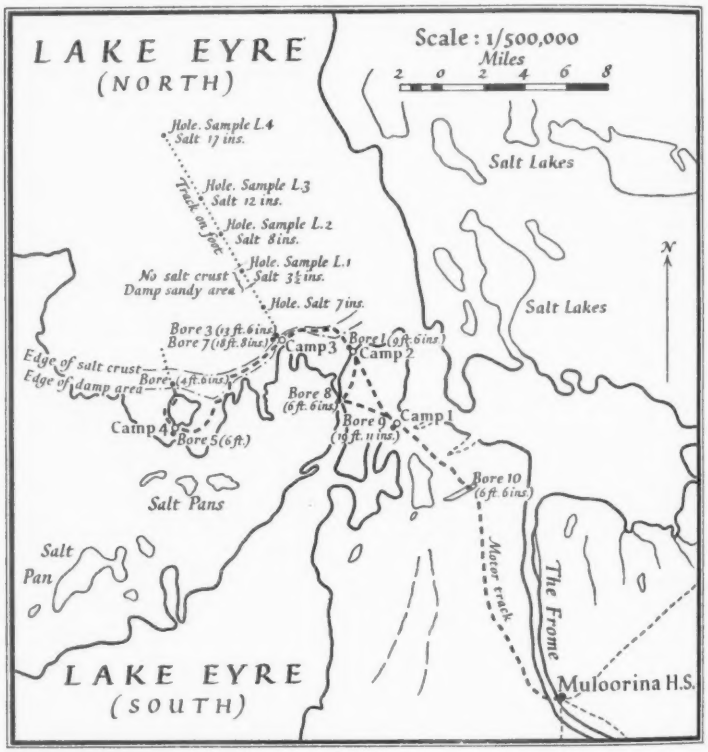


Fig. 3. The routes of the Ground Expedition, December 1929

it was going to be possible to run it on the surface. It was late evening, but we walked out a mile and a half, with bar and shovel, and dug some holes. The surface was bull dust near the shore, up to a foot deep, and below, damp gypseous clay. The lake margin was everywhere the same. This is blown sand and gypsum from the shore. It appears level, but must slope inwards slightly. At the mile and a half we were deceived in the same way as several others who have visited the lake shores. We thought we saw before us a long sandhill dotted with bushes. This indicated dry conditions, and we returned

and made camp, after getting the lorry down the rather steep bank. Before turning in we got out the boring tools and sank a hole 9 feet 6 inches deep, 200 yards from the shore, Bore 1 (see map, Fig. 3). It was in damp gypseous clay all the way below a foot of dry sand. Water-level stood at 3 feet 5 inches from the surface after three-quarters of an hour. The hole did not cave in, but the bar could be driven down the full 6 feet by hand anywhere within a mile of the shore. The boring kit was a 4-inch post-hole borer of a very efficient pattern, and rods of 1-inch iron piping giving a length of 30 feet. I had also had a 2-inch wood augur prepared for screwing into the piping, but I found the 4-inch borer much quicker to work with.

The surface was rather heavier going than the narrow lake we had crossed, but it seemed that the truck should do it, and we started off at daybreak next day with a full load straight ahead into the lake. We could just get along in bottom gear. After the first 100 yards we cheered and thought that success was assured. At a quarter of a mile the vehicle slowed down, stopped, and dug itself in, and we had to take off half the load, and use the irons to restart. We left a dump of water and petrol there and went on with a lighter load. I walked ahead with a thin 6-foot bar and the truck followed at intervals. Once the wheels got through the sand the damp clay gave difficulty, but only once on the lake did we sink down to the differential. At a mile from the shore the surface became damp and harder. At 1½ miles the sandhill error was exposed and explained. Here a salt crust began, about 1 inch thick at first, covering damp gypseous clay full of crystals. This crust is buckled up along lines several feet in length, giving from the air the appearance of ordinary sun cracks in clay, though it had been noted from the air that they were ridges and not cracks. Slabs of salt along the cracks rest against each other like roofing slates propped together in pairs, but within the area enclosed by these lines of tilted slabs the surface is quite smooth. The ridges rise up to 9 inches. It was now clear that the tessellated surface seen from the air on most of the lakes was a pink salt crust. Drift sand and dust give the colour, which from the air is identical with the colour of the surrounding country. The salt is white below the surface, except for patches coloured both pink and green by microscopic life. Specimens containing these salt organisms were sent to the Herzstein Professor of Botany, Jacques Loeb Laboratory, California, on a request through the Geological Survey. The appearance of sandhills in the lake from its shores is due to the miraging up of this salt crust, and the bushes are the dark shadows under the upturned slabs.

Mr. Lockhart Jack informs me that this buckling of the salt crust has been noted by him on other lakes in South Australia. The explanation seems to lie in thermal expansion. One would expect the slabs to fall on the contraction of the surface. They are held up by the ends becoming cemented in by the crystallization of further salt in the cracks and angles formed. In most cases the slabs are not actually leaning against each other, but projecting rigidly at an angle of 30° or 40°. They are quite difficult to stamp down. Where the crust is a foot or more thick it is still only the surface inch or so that is buckled up, with solid salt in the cracks below the slabs. Plates 7 and 8 show this surface well.

Owing to the colour, and the absence of vegetation, the shores of the lake had been difficult to distinguish from the air unless flying very low. It was a sur-

prise to find that they were banks 50 to 70 feet high, consisting of coarse sand and seed gypsum, and in places solid seed gypsum. It was often difficult to tell by inspection the proportion of seed gypsum in the sand, as both were clear grains. Biting the grains is the most ready way.

The truck was now a mile and a half from the shore, at the end of the crusty sand and beginning of the salt crust, from which it was separated by 100 yards of damp clay. I was afraid to risk the truck on the damp clay, so turned west, keeping the salt crust close on the right. I thought at first it was merely a salty delta from the Frome river, but realized later that it covered almost the whole lake. I expected to skirt round it and continue in. However we soon found that it followed the smoothed-out contours of the shore, varying from ½ to 4 miles from it. My plan then was to follow up the eastern side of the narrow 30-mile peninsula which lay west of us and stretches towards the centre, keeping on the margin of the damp area, which experience soon showed was the best zone for travel. Movement outside the lake-bed was now impossible owing to the sandhills running at right angles to the shore. We crossed opposite the neck connecting the lakes, and then were forced in close to the shore at a small peninsula, where we made our second lake camp, Camp 3.

This was our hottest day, the thermometer rising to 100°. We were very

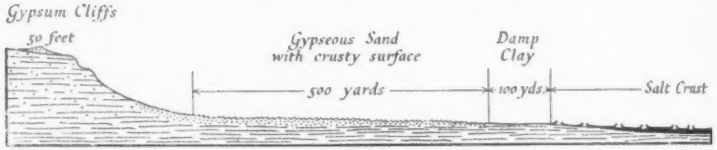


Fig. 4

fortunate in the weather, as there was no shade, cool southerlies keeping the temperature down; otherwise conditions on the lake would have been almost unbearable at that time of year. The nights were glorious as we lay in the open on the dead flat surface. In spite of the comparative coolness, so dry was the atmosphere that evaporation was going on at the rate of 1½ inches a day, according to our observations on tins of water.

At this point the profile of the margin of the lake was as shown in the sketch, Fig. 4, with the vertical scale exaggerated. By now we had established the zones of the shore, sandy gypseous foreshore of varying width from half a mile up to several miles, a narrow strip of damp clay, and then the salt crust extending almost to the far shore 100 miles away, as the aerial photographs indicated. Plate 8 shows these zones, looking shorewards from the salt crust. There was probably a slight slope from the shore to the salt crust, explaining why the salt does not come right in, but this was not noticeable, and we had no means of taking levels beyond the aneroid, which of course was not sufficiently sensitive.

While the stores were relayed to this point a hole 13 feet 6 inches deep was sunk, Bore 3, half a mile from the shore. The salt crust was 1¼ inches thick, and the remainder of the hole was in gypseous clay, the first 2 feet being blue, followed by 1 foot pink, then 5 feet blue, 1 foot 6 inches pink, and 4 feet blue. There were no large gypsum crystals in this hole. In other places they were flat, sharp-edged, and about the size of a penny. Immediately below the salt

crust in all places there was a thin layer, ¼ inch thick at most, of deep black slime like paint. On exposure to the air this rapidly goes brown, and becomes a mass of gypsum and salt crystals on drying. Heated in air over a burner it goes brown almost at once, and on ignition gives off strong sulphur dioxide fumes and turns bright red. The black colour is thus seen to be due to finely divided sulphide of iron. The slime is immediately below the salt crust, and the under side of the salt is a dirty green colour from minute forms of organic life. It is probable that this reduction of iron salts is the direct result of the work of anaerobic bacteria in liberating sulphuretted hydrogen *in situ*. It was at first thought that the black colour might be due to fine carbonaceous matter of plant origin from the shore, such as pollen, but the tests mentioned above discounted this. After standing all night the water had risen to 5 inches from the surface. Like all holes in the lake, this one stood without caving in, but the clay was very wet.

The next day we proceeded with the full load on a definite plan, to keep as near as possible to the salt crust, and work north. At times we got too far into the damp clay and had to use the irons, then again we would sink into the gypseous sand and have to lay the mats. Efforts to turn north proved fruitless. The damp clay strip prevented us from getting on to the salt crust. The island shown on the map was reached on the second day. We tried to go round to the north-east of it, but were forced in to the shore, where we saw the skeletons of three horses. Their tracks showed that they had come from the island. In this region there were some green shrubs on the banks and samphire at the lake edge. There had been a little rain recently. We cut across a bay and reached the south-west side of the island, having made 11 miles in the morning. The island rose to a height of 70 feet and was composed entirely of seed gypsum, blown up from the lake-bed in dune formation. There were some green shrubs on it. We made camp here, and then proceeded round the west side of it and thence a mile out from it, where we left the truck as the surface changed from the pie-crust or bull dust to damp white clay. The damp clay belt was here three-quarters of a mile wide. At the far side of it there were odd "pancakes" of salt, probably patches left after partial solution during the rains which had evidently fallen in the past few months, and then a solid salt crust. We walked out a mile on this salt and found it thickened from 1 to 2½ inches, with wet clay and flour gypsum below. On the return to the truck a 4-foot 6-inch hole was sunk. The clay was here full of gypsum crystals and at 4 feet 6 inches a solid bed, probably of dolomite, was encountered, which the tool was unable to penetrate.

I now decided that no useful purpose would be served by pushing on at the rate we were going for another day, which was all that remained in order to allow us to return to Marree within the week for which the men and truck were loaned. In that time I had hoped not only to reach the lake, but once having got on to its surface, to motor at a reasonable speed the 50 miles to the centre, and incidentally to recover the spears dropped from the aeroplane. I would not risk putting the lorry on the damp clay guarding the salt crust. The vehicle would not have sunk in this, but owing to the slippery nature of the clay, it might well have become immovable, as we had no other power available, such as horses or another motor, to move it. If we had reached the end of the

peninsula it is certain that the same difficulty would have confronted us, and there was every reason to believe that the coast of the lake would have been the same as it had been for the past 18 miles. A walk into the lake on foot would be the most profitable way to spend the time, and the cape at Camp 3 was the best place to start from. At the island camp, Camp 4, I put down a 6-foot hole 100 yards south of the island. The sand was here dry for 2 feet, with very stiff clay below, without gypsum crystals. A water sample was taken from the hole.

The next morning we soon reached Camp 3 again, travelling in our old tracks in top gear, and at 11.40 a.m. Charlie Kunoth and I started in on a course N. 35° W., and walked 12 miles out on the lake. This journey was a remarkable experience. As we left the camp, the lorry gradually rose on stilts, our companions stretched skywards as they moved about, and soon all was lost, even the shore, in waving mirage. We were in the centre of a pink disc. In places the scene was exactly like the frozen seas of the Antarctic, of the type known as pancake ice. The irregular areas of salt crust, bounded by their buckled edges, exactly resembled closely packed ice-floes, their rims turned up by contact and movement. Under pink sunset skies the ice-floes are often just the colour of this salt.

We walked rapidly over the smooth surface, halting at regular half-hour intervals for a spell, and to make a hole in the crust. At 2 miles the salt crust had increased to 7 inches thick. At 3 miles the salt crust disappeared again and we entered a damp sandy belt a mile wide, running north-east–south-west. This was of the nature of a channel in the lake, though it was not an obvious depression. The salt had been dissolved out. In this strip we saw a solitary dead needle bush, a small tree stem about 9 feet long with a few limbs, and round it were the skeletons of fifteen rabbits, which had probably made out on to the lake in search of water, and congregated to die around the only visible object. The rabbits had died out completely in the surrounding country, and their holes, partly drifted up with sand, were a great menace to our motor truck.

We made a hole 2 feet deep in this belt, at the tree stump. It was in coarse sand, and filled up with brine. There was no mud, and the bar could not be pushed down by hand. At 4 miles the salt crust was thickening again, and was 3½ inches through. At 6 miles it was 8 inches, with damp seed gypsum and white gypsum slush below, no sand or clay. The bar was pushed down 4 feet. At 8 miles the salt crust measured 12 inches through with loose salt crystals below, in brine, followed by seed gypsum like coarse sand. The brine filled up to 3 inches from the surface. The bar could only be forced down 3 feet. A foetid odour rose from the hole. We made our final halt at 12 miles and sank the last hole. The salt was 17 inches thick. It is a most tough and difficult material to dig through. Gypsum in a loose aggregate of small crystals underlay the salt.

The salt crust varied in appearance in different parts. In some places it was tessellated with cracks and upturned slabs, as shown in Plates 7 and 8, in others it was quite smooth, as in Plate 9. Again it would show curious small areas of disturbance in an otherwise smooth surface, as shown in the aerial photograph, Plate 5. The 12-mile point was such a place. Here the polygonal cracks had 2 to 3 feet sides, and were only markings, but scattered about were patches of dark-red dirty salt up to 30 feet across and 50 to 100 yards apart, which were

made up of concentric rings of upturned edges. The darker colour is due to the projecting slabs catching the red dust. These areas seemed to be depressions in the crust. Water had flowed in to them from all sides, over the surface, as was shown by the dry scum. The areas in Plate 5 are arcuate rather than concentric rings. The buckled slabs, as mentioned above, are only an inch or so thick, and the remainder of the salt crust below seems undisturbed. There was evidence here of recent rain. Water had lain on the surface of the salt, in a south-west wind, as the south-west sides of the projections showed a dry salt scum. An interesting phenomenon noted on the way out was that the surface ahead always looked much darker than that behind. We appeared all the time to be about to enter this dark area, but it receded before us. This was found to be due to the little pimples on the salt surface having collected red dust on the windward side, the south-west. They were reddish on that side and much whiter on the other, so that a few yards away from the observer the whole surface had a different hue in opposite directions. The reason was not discovered till the end of the walk, while lying down.

Darkness descended on us during the return, and as we had left no trail, and the compass was non-luminous, and the surface absolutely featureless, there was nothing but the stars to march on. We were glad at last to see a beacon fire lighted by our mates on the sandhills of the shore. I could see my companion was rather surprised that it was dead ahead. During our absence Professor Prescott and Mr. Kunoth had sunk another hole, Bore 7, on the salt crust at Camp 3. They got down to 18 feet 7 inches, and could go no further, the tool refusing to bore a hard white bed which proved to be a dolomite, though it was taken for solid gypsum at the time. Beneath a $1\frac{1}{2}$-inch salt crust there were alternate bands of stiff blue and red clay, blue for the first 2 feet 6 inches, then red for 1 foot, followed by 1 foot of blue, 7 feet 6 inches of red, and 6 feet 6 inches of blue. At 13 feet, the beginning of the last blue bed, gas rose up the hole. It could be heard bubbling up the bore, but would not ignite at the surface. The colour represents the degree of oxidation and would depend on conditions at the time of deposition. The hole filled with brine to within 5 inches of the surface. There were no large gypsum crystals in this clay. It was curious that they were sometimes present but not always.

On the return journey a visit was paid to the lake's neck. It was about 150 yards wide at the narrowest part, and here the skeletons of seven dead camels were seen. The bed was similar to the coastal zone of the main lake, a bull-dust surface, quite dry. Low sandhills border the neck on both sides. An animal might be bogged after rains, but we could at that time have taken the truck across. If these camels had been bogged, they must have been very weak at the time. A hole was sunk, Bore 8. There was 4 inches of dry sand on top, with 2 feet 6 inches of blue pug below, then coarse water-bearing sand. Further boring was impossible owing to caving. This was the only hole which would not stand without caving in. The bar was pushed down 5 feet, where gypseous clay was met with. Water-level stood at 3 feet below the surface. Another hole was sunk at Camp 1 in a bare patch in the sand-gypsum hills. These bare patches show a tessellation of cracks, not open, of similar dimensions to those of the salt crust on the lake. They were mere markings. The hole was taken down to nearly 20 feet in fine yellow gypseous sand all the way. The first

3 feet was bone dry and water had to be used to raise the borings, but below that it was slightly damp. No water was struck. On crossing the narrow dry lake again, a last hole was put down to 6 feet 6 inches, Bore 10. The bull dust was 3 inches thick, followed by 3 feet of yellow clay, 2 feet 9 inches of blue clay, then blue water-bearing gravel. The water rose to 4 feet 7 inches. All the waters mentioned were of coarse practically saturated brines.

Thus the motor venture ended. We had actually run our heavy lorry for 40 miles on the lake. If we had been able to put it on the salt crust the centre could certainly have been reached, as further in this crust could have held a locomotive. An attempt to run across the strip of damp clay with the empty lorry might have been successful as it was. There was no bog, and boots never even became muddy. Had we had in addition to the truck a light car or motor cycle, or even a pedal cycle, much more could have been done in the way of covering distance, but it is very unlikely that any further information of importance could have been obtained. Our examination of the shores, and the 12-mile walk out, coupled with the aerial photographs which I am now able to interpret, make me confident that the main features of the lake-bed after dry seasons are now known.

Animal Life

The larger animals had all migrated or died out in the area, as there was no water at all. Only such animals remained as could do without water. Horse, camel, emu, and kangaroo tracks were seen on the lake surface, but no living animals. On the shore, recent tracks of wild dog and fox were seen. As to birds, one magpie and one hawk were seen near Camp 1, but martens were common in the gypsum cliffs of the lake shore, where they live in holes made in the banks. Dr. Morgan informs me that the marten is known to live away from water.

The most interesting observations with regard to animal life were made on the lake itself. In the marginal area, up to 4 miles from the shore, and mainly on the bull-dust surface, there were numerous colonies of small black ants. The ants built small crater-like hills, wider at the top than the centre, like cotton reels. A cream-coloured lizard up to 9 inches long, ornamented with black spots, was also quite common. Its protective colouring was such that it would have escaped observation if it had only kept still. This lizard burrowed in the drier sand and under the tilted salty crust. The ants might obtain seed blown on to the lake, but in these bad times that would seem too precarious a livelihood. Possibly the micro-organisms of the salt provide them with food. The lizards' stomachs were found to be full of the ants. Mr. H. M. Hale, curator of the South Australian Museum, identified the lizard as *Typanocryptis lineatus* var., and remarked that the scales were rather smoother and colour different from that of the typical form. Mr. John Clark of the National Museum, Melbourne, determined the ants as a new species of *Melophorus* (Lubb), working on the contents of one of the lizard's stomachs. He found they were all of one species, and included all forms from the smallest workers to very large-headed soldiers, and were of a harvesting species from the mandible. They are black, with yellow antennae and legs, and approach *M. wheeleri* (Ford), but the latter is three times the size and red. The presence of the ants so far out on the lake showed the absence of water for a very long time.

Chemical Analyses

The analyses quoted were carried out by Mr. W. S. Chapman, through the courtesy of the Geological Survey of South Australia. It was decided to carry out firstly a complete analysis of several of the brines or bitterns, as likely to indicate the composition of the salts and to be richer in potash, and to follow with some of the salt samples, restricting the work to the determination of the constituents indicated by the bitterns. Accordingly the bitterns from Bores 1, 200 yards from the shore at Camp 2, and 3, half a mile from the shore at Camp 3, and Lake Hole 4, 11½ miles from the shore, were analysed for chlorine, sulphuric acid, carbonic acid, sodium, potassium, calcium, magnesium, silica, bromine, iodine, nitric acid, and oxide of iron and alumina. Subsequently the bittern from Bore 10 in the narrow dry lake near the southern shore of the main lake was analysed for the same constituents except bromine, iodine, nitric acid, and oxide of iron and alumina, and the surface salt from Lake Hole 2, and from 1 mile off the island, were similarly treated. A white efflorescence was very common beneath the surface salt crust and along cracks and under upturned slabs. This was analysed, and also a bottom sample from Bore 7 of the hard crust which stopped the boring, and a composite sample of all the material of this bore except the top salt crust and the hard bottom bed. These analyses are set forth below.

Water Analyses

	Lake Eyre Bore 1 *Grains per gal.*	*Lake Eyre Bore 3* *Grains per gal.*	*Lake Eyre Lake Hole 4* *Grains per gal.*	*Dry Lake Bore 10* *Grains per gal.*
Cl	10,582	12,137	13,231	8,120
SO_4	643	623	1,262	1,000
CO_3	2·8	4·2	13·6	3·5
Na	6,797	7,754	8,062	5,210·2
K	22	39	117	19
Ca	84	71	45	65
Mg	142	167	537	239
SiO_2	5·6	4·2	Nil	7
Br	3·0	2·8	7·8	Not determined
I	Less than 0·2	Less than 0·2	Not determined	Ditto
NO_3	Less than 0·6	Less than 0·6	Not determined	Ditto
Fe_2O_3 and Al_2O_3	Nil	Nil	Nil	Ditto
Total saline matter, grains per gal.	18,281·4	20,802·2	23,275·4	14,663·7
Ditto ounces per gallon	41·78	47·55	53·20	33·51
	Assumed composition of salts, grains per gallon			
$CaCO_3$	4·7	7·0	22·7	5·8
$CaSO_4$	279	232	122	213·2
$MgSO_4$	559	576	1,474	1,064·6
$MgCl_2$	114	198	937	93·6
NaCl	17,273	19,707	20,487	13,243·3
KCl	42	74	223	36·2
SiO_2	5·6	4·2	Nil	7
NaBr	3·9	3·6	10·0	—

	Lake Eyre Bore 1	*Lake Eyre Bore 3*	*Lake Eyre Lake Hole 4*	*Dry Lake Bore 10*
	Calculated composition of dry salt, per cent.			
$CaCO_3$	0·025	0·034	0·097	0·039
$CaSO_4$	1·526	1·115	0·524	1·454
$MgSO_4$	3·057	2·769	6·333	7·261
$MgCl_2$	0·623	0·952	4·026	0·638
KCl	0·229	0·356	0·958	0·247
NaCl	94·483	94·737	88·019	90·314
NaBr	0·021	0·017	0·043	—
SiO_2	0·036	0·020	—	0·047
	100·000	100·000	100·000	100·000

These water analyses showed that the bitterns were composed chiefly of common salt, with magnesium sulphate and chloride in minor amount, appreciable gypsum, very little potash, and almost negligible bromine and iodine. They were practically saturated solutions, and showed no reaction to blue or red litmus.

The analysis of salt was then confined to two samples, one from Lake Hole 2, 6 miles from the shore, and one from 2 miles off the island to the west, the results of which are given below.

	Lake Eyre Salt Lake Hole 2	*Lake Eyre Salt 2 m. off island*
	per cent.	*per cent.*
Insoluble in water ..	0·84	0·86
Water	0·82	0·63
$CaSO_4$	2·60	2·36
$CaCl_2$	0·44	0·50
$MgCl_2$	0·20	0·12
KCl	0·36	0·19
NaCl	94·92	95·45
	100·18	100·11

These analyses are similar for all practical purposes. They show that common salt vastly dominates, in fact the samples are not far from a table salt quality. If some of the gypsum from the bottom of the crust were omitted, the material would be of marketable grade, similar to the commercially exploited lakes in lower South Australia.

Analysis of the white efflorescence showed it to be almost identical with the above analysis, with only a little more water and magnesium chloride and a little less calcium sulphate. The common salt was 95·17 per cent., so that it was merely a recrystallization of the crust, and not a separation of any particular constituent. The hard bed struck at 18 feet 7 inches in Bore 7 was analysed and found to consist of 86 per cent. carbonates of lime and magnesia. The proportion of calcium to magnesium carbonate was 55·7 to 44·2, almost the exact proportions for dolomite, which are 54·3 and 45·6. Of the remaining 14 per cent., 7 per cent. was insoluble in acid, 4·8 per cent. was sodium chloride, and 1 per cent. water. This dolomite was the only indication of carbonates in quantity in the lake, and the depth of the bed could not be ascertained. Finally,

a composite sample from Bore 7, excluding the surface salt and the bottom hard-pan, was analysed with the following result:—

	per cent.
SiO_2	40·64
Al_2O_3	11·46
Fe_2O_3	1·30
MgO	2·69
CaO	2·20
Total H_2O	14·74
CO_2	1·56
Water soluble salts ..	25·57
	100·16

Water soluble salts	*per cent.*
$CaSO_4$	9·88
$MgSO_4$	0·59
Na_2SO_4	1·12
NaCl	13·98
	25·57

Thus common salt and gypsum formed the bulk of the 25 per cent. of soluble salts, and the remaining 75 per cent. consisted of clay, quartz sand, and other mineral fragments, in the proportion of 6 parts of clay to 5 of quartz sand, and 2 of other mineral fragments, assuming all the alumina to go to kaolinite. This may be taken as the approximate composition of the lake muds in the first 18 feet. The amount of carbonate of lime in the mud is seen to be about 3·5 per cent., the CO_2 satisfying most of the lime, with 9·88 per cent. of gypsum and 13·98 per cent. of common salt. The material was in the condition of a stiff plastic clay.

Discussion of Analytical Results

The great majority of the drainage basin, that part lying to the north-east of the lake, is occupied by the Lower Tertiary (Eyrian) and Upper Cretaceous (Winton) beds, both fresh water, and in Queensland a considerable area of Lower Cretaceous marine shales is exposed. The Eyrian beds everywhere include much sheet gypsum near the surface. The greatest additions of water must come from this direction. From the north-west enters the Alberga river, draining the granitic area of the Everard and Musgrave Ranges, and farther north the Finke from the old sedimentary and gneissic rocks of the Macdonnell Ranges. It is still a matter of doubt whether the Finke floods ever reach the lake. Pastoralists in the area think not. With regard to the Finke it is interesting to note that Sir Douglas Mawson and the writer recently inspected an occurrence of nitrate of potash in a limestone at the headwaters of this river, which was encouraging to the prospects of finding potash in Lake Eyre. From the south the Frome drains a Pre-Cambrian area of sedimentary origin, with some igneous intrusions. The many bores put down in the basin to depths of upwards of 5000 feet to tap the artesian water below have given complete information of the nature of the beds of the great Cretaceous basin, and there are no salt beds of any kind beyond the gypsum in the Eyrian series, whose origin is probably the same as that of the salts of the lake itself, though it antedates the latter and must have added much to the lake. Thus the salts have been derived from the drainage of normal, mainly freshwater, rocks, not notably rich in potash. The salt crust consists of 94 per cent. common salt, with magnesium sulphate, calcium sulphate, and magnesium chloride well represented. Sea-water salt is distinctly suggested. Mr. R. Lockhart Jack (Bulletin No. 8, Geological Survey of South Australia), from a study of ground water, has

established a strong case for the cyclic origin of the salts in the lakes of lower South Australia, that is, wind-blown salts from the sea, unable to return to it on account of absence of outlet, in the inland drainage system. Though so far from the sea, there seems no alternative to extending this theory for the origin of the Lake Eyre salts.

There had been some hopes of a concentration of the very soluble potash salts, on analogy with the famous Stassfurt deposits, whose origin was inland seas, a hope supported by the discovery of the limestone, of limited extent, carrying up to 14 per cent. of nitrate of potash in the Macdonnell Ranges, but the extraordinary and melancholy fact is disclosed that the salts and brines are subnormal as regards potash contents. The richer of the two salts analysed showed 0·36 per cent. of KCl, and the mean of the two was 0·27 per cent., while of the bitterns, the richest showed 0·96 per cent. of KCl or 0·5 per cent. of K, and the mean of three was 0·51 per cent. KCl or 0·27 per cent. K of the total salts. Of average sea-water salts, 1 per cent. is potassium (Murray) which is equivalent to 2 per cent. of KCl. Thus ocean salts are more than twice as rich in potash as the Lake Eyre salts. The proportion of sodium to potassium in sea-water is 28 : 1, while the richest bittern, that from Lake Hole 4, showed a proportion of 69 : 1.

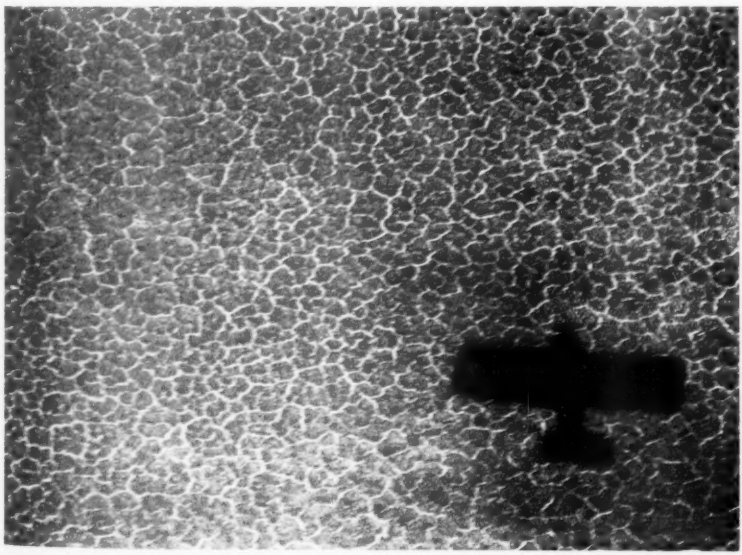
Assuming a cyclic origin for the salt, this relatively large loss of potassium is a difficulty. A certain amount of all salts will be adsorbed by the soil, and also plant life makes a demand on potassium. It may well be that these losses are in a much more equable proportion than 28 : 1, and if a large proportion of the potash were thus accounted for, the disproportion of the remainder of the two elements would be greatly increased. In an average of 573 soil samples from the arid States of America the ratio of soda to potash was 0·35 to 0·67 or 0·52 : 1 and from 696 analyses in the humid States the ratio was 0·14 to 0·21 or 0·66 : 1 (Hilgard). The proportion of potash is higher in arid regions and potash is almost twice as abundant as soda.

The richest bittern in Lake Eyre, Lake Hole 4, gave 117 grains of potassium to the gallon in a total of 53·2 ounces of salts. The figures for the other two bitterns were 39 and 22 grains only. These figures are of the same order as for lakes in lower South Australia, Lake Bumbunga, north of St. Vincent's Gulf, giving 75 grains per gallon, while Lake Macdonnell, near the coast at the head of the Great Australia Bight, gave 212·8 grains, and Lake Eliza, on the coast in the south-east of the State, 211·4 grains. The bittern from the crystallizers at the salt works (solar evaporation of sea-water) at Price, at the head of St. Vincent's Gulf, give 694 grains of potassium to the gallon with total salts at 56 ounces (figures from Jack, Bulletin No. 8, Geological Survey of South Australia). Thus the bitterns from solar evaporation of sea-water are much richer in potash than any of the natural lake brines. It will be noted that the potash is higher in lakes nearer the coast. The supply of all salts will there be greater, on the cyclic salt theory, the drainage areas are smaller, and the opportunity for the removal of potash less.

Of the three Lake Eyre brines analysed, that from Bore 1 came from close inshore, from Bore 3 on the edge of the salt crust, and from Lake Hole 4 from 11½ miles from the shore. The analyses show that the common salt was purer inshore, and that the magnesium and potassium salts increased notably with

Phot. C. T. Madigan

5. Arcuate buckling of salt crust east of peninsula in Lake Eyre North



Phot. H. Thomas

6. Salt crust near south-east margin of lake from 200 feet altitude

UNIV. OF MICH.

Phot. C. T. Madigan

7. The buckled salt crust from the ground

Phot. C. T. Madigan

8. The south-east shore of Lake Eyre North from the salt crust

Phot. J. A. Prescott

9. A smoother area of the crust

distance from the shore. Calcium sulphate, with common salt, decreased. This is the natural result of the net inward movement of waters into the great evaporating pan, carrying the more soluble salts with them, and tending to leach them from the marginal deposits.

Summary

The lake bed was quite dry from August to December 1929. There is no permanent water. A salt crust begins near the shore, and occupies at least two-thirds of the lake surface. It may be absent at the north-west end. It increases from 1 inch thick, at a half to several miles from the shore, to 17 inches at 11½ miles from the shore, and is probably thicker still farther in. It is a solid, coarsely crystalline mass, of the nature of rock salt, with a pink surface due to dust, but white below. The salt crust is underlain by damp gypseous clay to a depth of at least 18 feet 7 inches, where a dolomite bed was encountered. The level of ground-water is only a few inches below the surface. The salt is 95 per cent. common salt, with a notable amount of gypsum, and very small amounts of calcium, magnesium, and potassium chlorides. The deficiency in potash is remarkable.

Bores in the Great Artesian Basin show no salt formations in the Mesozoic strata, and there are none in the Lower Tertiary or Eyrian, which occurs in patches to a maximum thickness of 360 feet. The origin of the salt is in Upper Tertiary to recent times, and the cyclic theory seems the most reasonable.

The salt shows no obvious seasonal banding. The solution of a portion of the salt would cause a settling of sand and dust, and evaporation and recrystallization would put clean white salt above this sediment, as happens in the lakes annually harvested for salt in lower South Australia. This absence of banding indicates either that muddy waters do not flow on to the lake, it being only affected by local rainfall at present, of which there was evidence at the time of inspection, or that the whole crust is occasionally completely dissolved. It requires 6 inches of water to dissolve 1 inch of salt, so that 8 feet 6 inches is required to dissolve the 17-inch crust. It has been shown that the most generous calculations only provide for a flooding of 56 inches in a year, against an evaporation of 100 inches, so that if all the run-off arrived at one time the crust would not be half dissolved. The conclusion is that any river in flood scarcely affects the lake at all, except near its mouth. This was borne out by the absence of drift wood on the lake. The thick accumulation of clean salt of rock salt texture may be a relic of former more fluvial times, or a concentration at the surface of salt by evaporation and capillarity from the saline muds below. A local rain on the lake of an inch or two would only effect up to the first one-third of an inch of already dirty salt. Not much sand and dust can accumulate on the flat smooth surface, except where it forms into actual dunes.

There were heavy rains in December 1929, which produced a record flood in the Diamantina. Up to the time of writing (April 1930) no one has since visited the lake near the mouth of this river, but at the end of March 1930 Charlie Kunoth, Junior, got out to our old starting-point, and found that the Frome had wetted the surface to a mile from its mouth only and the water was all gone (the Frome only ran a moderate flood), but our motor tracks were still as we left them. Water is at present seen in the south lake from the railway

line, but Kunoth found the neck dry and no water had passed through it into the north lake.

There are no islands in the lake, which to the eye is a dead flat plain, other than those shown on the map near the shore. The salt crust was more noticeable from the air in the southern parts of the lake, which agrees with Mr. Halligan's reporting of water there. He probably saw very shallow water in 1922. The buckling of the upper portion of the salt crust is an interesting phenomenon. The presence of mound springs along the western margin of the lake was confirmed.

It would now be of the greatest interest to take a boring plant out on to the lake and put down a hole to several hundred feet, or until the Cretaceous formations were entered.

REPRODUCTIONS OF NOTABLE EARLY MAPS

EDWARD HEAWOOD, LIBRARIAN R.G.S.

REPRODUCTIONS of old maps are now the fashion, and students are better provided than ever before with the means of studying and comparing such documents, while modern methods of colour reproduction have made it possible to picture them in the pleasing and harmonious colours of the originals, where expense has not stood in the way. In the present collective notice of recent publications of the kind it will be convenient to take them in the chronological order of the originals and—with a passing reference only to the earliest of all, the Society's own coloured reproduction of the Dalorto chart of 1325, edited with notes by Mr. Hinks—begin with the excellent facsimiles of two early Portolan atlases which are among the treasures of the Bibliothèque de Lyon, and are reproduced as part 8 of a general series dealing with important documents there preserved.* They have the advantage of a commentary from the competent hand of M. de la Roncière.

The first nine plates are devoted to a fine atlas by the Genoese Pietro Vesconte, not recorded by Kretschmer, made at Venice probably about 1319, though the date in the signature is illegible. It is a real work of art, with a cover of wood finely inlaid, the writing of the maps beautifully clear, and the sheets ornamented with figures of saints in the corners. In his remarks on the work of Vesconte in general M. de la Roncière returns to his theory—for which there is certainly a good deal to be said—that the advance registered by Vesconte's maps is a result of the campaigns by sea of his compatriot Benedetto Zaccaria, the influence of which is to be traced in many of their details. Like Kretschmer, he holds the maps accompanying the Sanudo MSS. to be Vesconte's work, and

*LES PORTULANS DE LA BIBLIOTHÈQUE DE LYON. By CH. DE LA RONCIÈRE. (Documents Paléographiques etc. publiés sous la Direction de Henry Joly, Conservateur. Huitième Fascicule.) *Lyon, Mai* 1929. 12×10 *inches;* 24 *pages;* 14 *plates.*

remarks that a new proof of this is afforded by the Lyon Atlas, where much of the nomenclature is identical with that in the others. Such cooperation with Sanudo explains Vesconte's move from Genoa to Venice, whither Sanudo returned in 1306 after his visit to Palestine.

The second atlas is of somewhat less, but still considerable, importance. It is unsigned and undated, but the ornamentation is of the Lombard school, while the nomenclature (which differs from Vesconte's but shows resemblances to Giroldi's Venetian map of 1522) points to Venice as the place where it was drawn, and its date is thought to be about the end of the fourteenth century. M. de la Roncière finds that the draughtsman betrays no knowledge of the voyages of the Zeni, but if they were, as he allows, fabulous, such knowledge would surely be impossible, as their fabrication would date from well on in the sixteenth century.

Of each atlas one sheet is reproduced in colour, apparently by a combination of photography and hand-colouring. The style of production is attractive, and the edition limited to 350 copies. Mention is made of two other MSS. atlases of later date possessed by the Library, but we are not told whether or not these will be reproduced later.

We come next to the American Geographical Society's fine coloured reproduction of the Leardo Map of 1452 or 1453, presented to that Society in 1906 by Mr. Archer M. Huntington.* The maps of this cartographer, though forming a sub-group of their own, are fairly representative of the geographical ideas of the half-century before Columbus. So far three are known, but the two others are both smaller and cruder than the present specimen, as they are also earlier (1442 and 1448). All had been previously reproduced, but in a far from adequate manner, and in the present facsimile students for the first time possess one worthy of the subject. It is accompanied by a full description and commentary by Dr. J. K. Wright, whose previous studies of mediaeval geography made him particularly well qualified for the task.

A special feature of the Leardo maps is the provision of a calendar encircling the map proper, with explanatory text below. In the specimen under notice it occupies ten concentric circles and deals *inter alia* with the dates of Easter for ninety-five years, the moment when the sun enters each of the signs of the zodiac, the mode of calculating the phases of the moon, and the lengths of the days in hours and minutes. Another characteristic of all three maps is the representation of the *Oikoumene* after the mediaeval conception of a circular mass of land surrounded by water. But, as Dr. Wright judiciously observes, this does not mean that the Earth was regarded as a flat disc, for Leardo was clearly a believer in the Earth's sphericity. He was not even showing a complete hemisphere, but a circular portion of the Earth's surface (corresponding with the then-known world) lying north of the Equator, for the fiery and uninhabitable equatorial zone is placed at the southern edge of the map just as the Polar belt, uninhabitable through cold, occupies a similar position in the north. A realization of this fact would remove many misconceptions as to the

*THE LEARDO MAP OF THE WORLD, 1452 or 1453. By JOHN KIRTLAND WRIGHT. (American Geographical Society, Library Series No. 4.) *New York* 1928. 8×5 *inches;* iv+74 *pages; key-maps and large facsimile, the latter separate.* $15.

ideas of certain early map-makers who have been unjustly reproached with holding the flat-Earth theory. For the shore-lines in the central part of the map Leardo depends mainly on the Portolan charts, while he extends the picture outwards by using information recorded by classical writers, with additions from the reports of mediaeval travellers. His map is closely related to those of the Catalans, particularly that in the Biblioteca Estense at Modena; but as each gives details not to be found in the other it must be a case of derivation from a common ancestor.

The larger part of the memoir is taken up with a detailed discussion of the contents of the map, an attempt being made to trace their sources, and to identify the places named. The suggestions under the latter head seem at times a little venturesome. Dr. Wright divides the map into eleven sections, and for each of these, as for the map as a whole, key-maps are supplied, in which each name or inscription receives a reference number, employed also in the Commentary. This is a convenient method, worthy of being generally followed. There is a useful bibliography, and an explanation by Mr. A. B. Hoen, under whose direction the work was done, of the process used for the colour reproduction—a technical matter, but one which will be of interest to those responsible for similar undertakings. Compared with some attempts of the kind the result is decidedly successful.

While the Leardo map is of interest as a monument of the early speculative period, the next item belongs to the time when a broader and more positive basis was available through the discoveries of Columbus and his successors.* The unsigned and undated map preserved in the Royal Library at Turin has been often mentioned, but its importance has hardly perhaps been fully understood. It has now been made accessible to students by the care of Professor Magnaghi, whose reputation as an authority on the history of geography vouches for the value of the accompanying discussion. This runs to nearly one hundred folio pages, and leaves little relevant to the subject unconsidered.

The importance of the map is held by Professor Magnaghi to rest on the following facts: (1) that it is the first world-map made after Magellan's voyage and therefore the first to give a generally correct idea of the distribution of land and sea; (2) that it is of the class of "Padrones Reales" or official charts made at the Casa de Contratación for the instruction of pilots, being practically the only early specimen of these to have survived; it is in fact the only important Spanish map between La Cosa (1500) and the Weimar-Ribero group of 1527–29. In the interval it was the Portuguese type, to be placed, as Magnaghi has previously insisted, to the credit of Amerigo Vespucci, which held the field. The "padrones" were being constantly improved and obsolete ones destroyed, so that most of the surviving maps are such as were made for high personages, and not for practical use. By contrast with such the Turin map is without decoration, shows no trace of the influence of Ptolemy, but gives just the details that would be useful to sailors. Its authenticity is also vouched for by its correct orthography.

*IL PLANISFERO DEL 1523 della Biblioteca del Re in Torino. By ALBERTO MAGNAGHI. *Firenze: Otto Lange* 1929. 14×10 *inches; 92 pages; Facsimile Maps. Lire* 150.

The map, which fills three sheets of parchment and is of unusually large size, bears no date or signature, and Professor Magnaghi's first task is to endeavour to place it in its correct setting. Showing the results of Magellan's voyage, it cannot be before September 1522, while the failure to take cognizance of discoveries made very soon after that date—and of some in fact before it—proves that it cannot be much later. That it was before 1524 is indicated by the placing of the line of partition east of Java, whereas at the Junta of 1524 the Spaniards maintained that it ran much farther west. Again the legend off Tidore: "here they loaded" [spices], seems to show that Magellan's voyage was so recent that it was unnecessary to name the voyagers referred to, and probably that to illustrate that voyage was the special purpose of the map. The Italian nationality of its author is shown by italicisms in the place-names, and as Juan Vespucci and Sebastian Cabot were the only Italians of influence in the *Casa* at this period, the suspicion falls on one or other of them as concerned in the making of the map, or of the original from which it was copied. And the evidence for Vespucci (who was official pilot and cosmographer uninterruptedly from 1512 to 1525) is supported by the unusual abundance of names on the coast of Venezuela and Darien explored by his uncle, including a "Valdamerigo" here found for the first time. One or two other maps have been attributed to Juan Vespucci, particularly the large world-map now owned by the Hispanic Society of America (see *Journal*, 67, 1926, p. 82); but from a consideration of their many inaccuracies Professor Magnaghi concludes that they cannot be the work of one holding so important an official position. He has a useful section on other maps of the period deserving of study in connection with Magellan's voyage, particularly that of Nuño Garcia de Toreno,* dated 1522 and also preserved in the Turin Royal Library. This was made at Valladolid, where the Spanish court was staying when the *Victoria* returned, but it shows only the region of the Moluccas, having evidently been drawn in haste before the general results of the voyage could be worked out, as they were more fully in the larger map.

The question of absorbing interest at this time was naturally that of the position of the line of demarcation relatively to the Spice islands, and an important section of the memoir deals with the history of this line, and the dodges to which the Spanish cartographers had recourse to bring these islands within the Spanish sphere. The large Turin map was evidently drawn with a special view to this end, and Professor Magnaghi gives reason for believing that longitudes in South America were deliberately falsified with a view to upholding the Spanish contention. All this is preliminary to the detailed examination of the contents of the map, which is carried out with exceptional thoroughness. The more important sections, *e.g.* those relating to Central and South America, are minutely examined, and an attempt made to trace the origin and identity of all the names, help being thus given towards a solution of some doubtful points in the history of voyages to this part of the world. For this laborious work students are under a debt of gratitude to the Professor. While the study as a whole involves a considerable amount of hypothesis, the arguments appear generally sound, and the memoir, which is elucidated by copious notes and

*Toreno is a town in Spain, though the cartographer has been sometimes, by a not unnatural mistake, assigned to Turin.

references to authorities, is one which no student of the period can afford to neglect. The reproduction consists of a much-reduced version of the map as a whole, followed by six sectional sheets, with an unusually wide overlap, which greatly facilitates their study. These too are on a somewhat reduced scale, but with the help of a lense the names are for the most part easily legible.

Among more extensive *Collections* of map reproductions, brief mention must first be made of the two parts already issued of Sig. Caraci's 'Tabulae Geographicae,' although neither is quite recent.* The publication is on a rather more modest scale than some others of the kind, and some of the maps are considerably reduced. They are all little known but of considerable interest for the history of cartography, and are accompanied by a valuable commentary. In the first part the most important item (occupying nine sheets out of twenty) is the large MS. map made by Lopo Homem in Lisbon in 1554, which is now at Florence. It has been known to a few previous writers, but never before reproduced. Two of the other maps, both by English hands, were referred to in the *Journal* in 1925 (vol. 66, p. 383) on the authority of a preliminary description by Caraci. We have also a map of Europe by Diogo Homem, 1563; one of America by the Venetian publisher Forlani, 1574; one of the Indian Ocean by the Dutch chart-maker Cornelis Doetz (round 1600); and one of the North Sea by Evert Gysbertzoon, 1601.

The second part reproduces (1) an anonymous Italian Atlas, in MS, in eleven sheets, probably of the end of the sixteenth century; (2) a large printed Italian map of the New World. Both have been practically unknown to students, and both are discussed exhaustively by Sig. Caraci, who endeavours to trace their sources, and their relationships with other maps of the period. He concludes that the anonymous atlas was either the actual work of the well-known draughtsman Martines, or made under his direction; and though it belongs to a late and somewhat discredited class of MS. atlases, it appears to have some claim to consideration as embodying material collected from various quarters and not merely a stereotyped picture. The second item is one of a series of large maps of the continents, brought out by the important Venetian firm of Bertelli and Camozio, and now in the Museo Correr at Venice. Attention was first called to this in 1923 by Professor Almagià, who regarded the set as the first attempt at a representation of the whole world, uniform in execution, and on a large scale; the America being the largest of that part of the world yet known from the sixteenth century. This map has also been discussed by Vignaud and Wagner on the basis of a copy now owned by Sir Leicester Harmsworth, Vignaud attributing the map to Gastaldi, and regarding it as the first in which his belief in a strait separating Asia from America found expression (see *Journal*, 58, 1921, p. 396). While admitting the great indebtedness of the map to the Gastaldi-Ramusio circle, Sig. Caraci dissents from the view that Gastaldi was the actual author, and puts the date somewhat later—not much before 1574. He also declines to accept Wagner's suggestion that both the map in

*TABULAE GEOGRAPHICAE VETUSTIORES in Italia adservatae. Reproductions of Manuscript and rare printed maps, edited and explained by G. CARACI. Vols. 1 and 2. *Florence: Otto Lange* 1926, 1927. 20×14 *inches*. Vol. i, [ii]+18 *pages*; 20 *plates*. £4 4s.; Vol. ii, [ii]+19–48 *pages; plates* 21–41. £4 10s.

question and that of Forlani given in Part 1 of the present collection derive from a Spanish original by Diego Gutierrez.

Since we reviewed, in vol. 71, 1928, p. 186, the first part of Dr. Wieder's fine series of 'Monumenta Cartographica,' two others have appeared, produced in the same excellent style and each containing at least one item of outstanding interest.* In Part 2 we have at last a full-size facsimile of Peter Plancius's great world-map of 1592, of which the one surviving copy, in the Colegio del Corpus Cristi at Valencia, was finally established as the missing masterpiece through Dr. Wieder's examination of it during his visit to Spain in 1914 (see *Journal*, 46, 1915, p. 159). The map is in poor condition, but Dr. Wieder states that its details are as legible in the facsimile as in the original. The accompanying memoir brings together just what we want to know both as to the history of the map and the geographical labours of Plancius, which surprise us by their extent and variety.

It may be recalled that the copy at Valencia does not bear Plancius's name, which may have appeared in the text intended to be added at the foot, but it is proved to be his from its close agreement both with references in contemporary records and with the detailed description printed in 1594 by Blundeville in his 'Exercises.' Nor is the name of the Amsterdam publisher Claesz (known to have been responsible for its issue in that city) now visible, being replaced by that of his Antwerp contemporary, Vrient, in printed slips pasted on. The names of the Dutch engravers, Van Doetecom, are to be seen however in a cartouche below South America. It is formed of eighteen whole sheets and two extra strips, and is coloured and heightened with gold. There are tables giving the values of the degrees of longitude in each degree of latitude, and a scale of miles in nine different systems. The projection is simple cylindrical, and as the net extends to the poles, the distortion thereabouts is enormous. After sketching the history of the map Dr. Wieder gives a brief description of its geography, which while agreeing in many ways with other maps produced in the Netherlands, shows a distinct advance in some directions. Its primary source is shown to be Mercator's big map of 1569, many of the details in this being exactly reproduced, but there are a good many additions. For all east of the Cape of Good Hope Plancius abandoned Mercator, following Portuguese models, and throwing aside all attempt to harmonize the new discoveries with traditional geography. A recently discovered set of special maps by the Portuguese cartographer Laso helps to show the extent of Plancius's indebtedness to such sources, though a general map by Laso, probably followed more closely, is lost. Ortelius supplied some details: thus the 1584 map of Ludovicus Georgius, printed by Ortelius in his Atlas, was followed for the interior of China. Dr. Wieder mentions a certain legend taken from this, but does not make it plain that the whole of the map is closely copied, including the representation of the Great Wall. Nor does he attribute to Ortelius another detail

*MONUMENTA CARTOGRAPHICA. Reproductions of unique and rare maps, plans and views in the actual size of the originals. Edited by Dr. F. C. WIEDER. *The Hague: Martinus Nijhoff.* 31 × 23 *inches. Vol. II*, 1926, *text* viii + 27–60 *pages; plates* 26–50; *Vol. III*, 1929 (1928 *on cover*), *text* viii + 61–88 *pages; plates* 51–75. *Each* £9 (*to subscribers to the five volumes*).

derived from him—the islands of S. Felix and S. Nabor off the north-west coast of South America. For the north of Europe and the adjacent polar region Plancius naturally had recent Dutch information, and it is clear that he used Doetz's map of the Northern Navigation (1589) reproduced by Dr. Wieder in the first part of the 'Monumenta.'

A valuable section is the very full bibliography of Plancius's geographical output which, including re-issues, runs to eighty items, seven of them not yet discovered. In 1589 he certainly had some hand in the preparation of the Celestial Globe of Van Langeren. Five maps in a Bible of 1590 bear his signature, and in or about 1592 he brought out a number of special maps besides the world-map. An unknown map of Asia of the same date, mentioned by Claesz, may be represented by an anonymous version of 1600, described as a fine piece of work. In 1594 the single-sheet world-in-hemispheres, afterwards used in Linschoten's 'Itinerarium,' was first issued, as well as a series of charts on Mercator's projection, not now known. In the same year he claimed the invention (perhaps in conjunction with Matthys Syvertsz) of a new method of taking latitude and longitude, though its nature is not recorded. In 1595 an English version of the big world-map, since lost to sight, was brought out in London, and in the same year appeared Barentsz's Atlas of Mediterranean charts in which Plancius had a hand. In 1599 he wrote treatises, preserved in MS., on the finding of longitude and on sailing to the East Indies, accompanied by an extensive table of compass-variations in different parts of the world, by the help of which he claimed that longitude could be determined. These tables were printed by Stevin in his work 'De Haven-vinding' (1599) of which an English translation also appeared. Other maps and globes, with re-issues of earlier versions, continued to appear till at least 1614.

Of these later productions the most intriguing is a large map in hemispheres (1607), known only from reprints of 1651 and 1676, which show that it very closely resembled Blaeu's map of *c.* 1605, and might be regarded as merely a copy of it. Yet in a note on his map Plancius dwells on the many maps in his possession which had helped in its making and Dr. Wieder hints that the original issue may possibly have been earlier and that it was Blaeu who was the plagiarist. He does not refer to the similarity also to be seen between Blaeu's map and Hondius's of *c.* 1611–18, and therefore between the latter and Plancius's. In view of the cordial relations between the last two there would be nothing surprising in the re-issue by Hondius of a map originally sponsored by Plancius, particularly if, as is possible, he had also been concerned in its first publication. This shows how far we are from a full knowledge of the cartographical history of the period.

Two other items in this second part are intimately associated with Plancius's first big map, and again suggest problems. Some years ago Dr. Wieder called attention to the record of an agreement between Renert Lans and the publisher Van Langeren for the issue of a world-map as large as Plancius's, but which was to be better engraved and otherwise improved. Dr. Wieder reads the statement as implying that the map was to be regarded as a new edition of the 1592 map, and expresses surprise that on examining a copy lately brought to light (portions of which he reproduces) he should have found it to be "a new map." But the terms of the agreement surely imply that its authors regarded

their map as much more than a re-issue, and though Plancius is certainly closely copied, there are other examples of quite as bare-faced plagiarism. His reading of the agreement leads Dr. Wieder to suggest that an unknown second issue of the 1592 map may have been the basis of the Rans–Van Langeren map, and that the improvements may have been Plancius's own work. The grounds for this idea seem hardly sufficient, even though Dr. Wieder has lately discovered one sheet of a re-engraved issue of Plancius's original map, which he thinks may possibly have been that produced in London in 1595. The paper is similar to some used by Hondius in 1605–06, and it seems quite possible that the latter was responsible for the London issue, though this view is not definitely put forward. The sheet in question is also reproduced.

Special mention must be made of the fine reproduction of the one copy known of Clusius's map of Spain, brought out by Ortelius in 1570. It was based on personal investigations undertaken at Ortelius's instance in view of an improved map in the latter's Atlas. The data however proved too extensive for publication in an ordinary atlas map, and were therefore published separately in four large sheets—an improvement on anything then existing. A reduced version was given in the Atlas.

The whole of the third part of the 'Monumenta' is concerned more or less closely with Blaeu's great world-map in hemispheres, probably first issued about 1648, of which the Society possesses one of the two recorded unmutilated copies, described in the *Journal* at the time of its presentation by Sir Arthur Paget (vol. 55, 1920, p. 312). From the use of the word "gratulabundus" in the dedication to Bracamonte, Spanish negotiator of the Treaty of Munster, Dr. Wieder concludes that the issue of the map was practically contemporaneous with the signing of the treaty and therefore to be definitely assigned to 1648. In a general appreciation of the map he regards it as the outstanding monument of seventeenth-century cartography, not to be improved upon for a century and more. Embodying the results of Dutch exploration and enterprise in the fifty-six years after Plancius, it is substantially correct in its general picture of the world. Yet, he says, it is essentially a sea-map, for exploration down to its date was chiefly concerned with the coasts, and for the interiors Blaeu was forced to go back to the Middle Ages, both for methods and details. From this Dr. Wieder draws the moral that away from the centres of Western civilization and the *coasts* of more remote regions, the geographical knowledge of the time was extraordinarily scanty. But surely some material did exist for an improved picture of parts away from the coast-lines, though Blaeu did not use it as he might, his information being in some ways, as Dr. Wieder allows, behind that of Plancius. He was content, in fact, to copy his predecessors to a considerable extent, and it is the imposing technique of his productions that appears to be their outstanding feature. On the other hand, a considerable further advance took place well within the century after 1648, for what Sandler has well termed the "Reformation of Cartography" is to be placed about 1700.

The present reproduction of the map (both as a whole, on a reduced scale, and in full-sized sections) is made from a copy lately secured (through Dr. Wieder) for the Naval Museum at Amsterdam, and in this, as in the R.G.S. copy, the sheet containing China is a re-issue of *c.* 1655. For the sake of comparison Dr. Wieder reproduces the original issue of this sheet from the mutilated copy of

the map in the British Museum. He also gives a reduced facsimile of a close copy of the whole map first issued by De Wit *c.* 1660, and twice re-issued within the next half-century.

As when dealing with Plancius, Dr. Wieder is at his best in his very thorough bibliographical treatment of the output of the Blaeu firm, and with his help students can for the first time form an adequate idea of its extent. The separate maps in his list, including re-issues, run to 127 items, many extremely rare or known only from late copies. We are impressed with the number of maps of large format (up to 127 cm. or 4 feet 2 inches in length), both of continents and separate countries, which issued from the firm's workshops. An interesting point is the possibility hinted at that there may have been more collaboration between the great Dutch firms than we are wont to suppose. We find that Blaeu's large maps of the continents, first published in 1608, were republished by Hondius in 1624, Blaeu's name remaining as author.* On the other hand, some of the maps in the early editions of Blaeu's Atlas were really, it seems, the work of Hondius, for in a unique set of forty-two maps (all on similar paper) discovered in Holland in 1905, thirty-four still bear Hondius's name, though it was afterwards replaced by Blaeu's. The section on the early history of the general atlas (globes, the sea-atlas, and books, having previously been dealt with) is of much interest. Besides the set of maps just referred to, which Dr. Wieder regards as Blaeu's first essay at a collection in atlas form, he describes an 'Appendix' of 1630, known only from a copy in the British Museum (the usual date being 1631), and an equally unique German set of 1634. This is still in one volume, the more complete atlas of 1635, published in four languages, running to two volumes.

Another fine collection of map-facsimiles, published at the end of 1929, is the volume entitled 'Monumenta Italiae Cartographica,' collected and illustrated by Professor Almagià of Rome and produced by the Istituto Geografico Militare at Florence. From its more special character it may be reserved for separate consideration.

G. A. WALLIN AND 'THE PENETRATION OF ARABIA'

MRS. M. TRAUTZ

IN the history of Arabian exploration G. A. Wallin, the forerunner of Burton, Palgrave, and Doughty, takes an honoured place. Yet only readers of Swedish have so far really been in a position to appraise his personality and the full scope of his work. For European scholarship Wallin stands or falls by two papers in the *Journal of the Royal Geographical Society* (vol. 20, 1850, pp. 293–344; and vol. 24, 1854, pp. 115–207). They contain a mass of information about the parts of Arabia he visited, in very compressed form, and their tone is quite impersonal. In that most fruitful book 'The Penetration of Arabia' (1904), the late Dr. Hogarth, in his very generous appreciation of Wallin's work, was yet

*A set of these acquired by the Society a few years ago (*Journal*, 60, 1927, p. 233) appears to be a much later Italian re-issue.

led astray in one important and several minor points, relying as he did solely on the two papers. He did not know that copious extracts from the diaries and letters, with a short biography, were published at Helsingfors in 1865 (S. G. Elmgren, 'Georg August Wallin's Reseanteckningar från orienten åren 1843–1849'). Knut Tallqvist has since written a fuller biography, with additional letters ('Bref och Dagboksanteckningar af Georg August Wallin,' Helsingsfors, 1905). Neither book has been translated; both are scarce. Wallin was not a Swede, without qualification, but a Fenno-Swede: *svensk* but not *rikssvensk*, and always called himself a Finn. His fame is still green in Finland, so that his countrymen may well insist on accuracy on this point.

Much more important is another misapprehension. At the date of Wallin's Arabian journeys (1845–1846 and 1848), the Wahabi power of Southern Nejd had not recovered from the crushing blows dealt by the Egyptians in 1819 and in later expeditions. The centre of power in Central Arabia was then in Northern Nejd, in the nominally tributary Shammar state, at Hayil. Hogarth supposed that Wallin's journey there was undertaken for political rather than scientific reasons: "In view of all the facts, one can hardly doubt that this distinguished scholar, though he had all the curiosity of an explorer who travels for the sake of pure science, was in fact commissioned by Mehemet Ali to make a report on the rising power of Jabal Shammar" (Hogarth, *op. cit.*, p. 161). This supposition has been resented in Wallin's own country, and indeed, to any one familiar with Elmgren's and Tallqvist's books, it seems singularly baseless. Perhaps Hogarth was influenced by a supposed analogy with W. G. Palgrave, whose patron was Napoleon III. Perhaps Wallin's two papers gave him the impression—a very false one—that the journeys had been carried out with ease, and according to plan, suggesting that Wallin could command powerful political influence of some kind. Since Hogarth does not name his facts it is hard to refute him briefly. Tallqvist (*Ztschr. f. Assyriologie*, Bd. 27, p. 103) says of Hogarth's supposition: "An sich ganz unberechtigt, bedeutet sie überdies ein gänzliches Verkennen des Charakters Wallins." This is abundantly true, but only convincing to those familiar with the diaries and letters. One can only point out how he actually spent his time in Egypt and Arabia, financed his journeys, and how the rumours as to his being in Egyptian service probably arose.

Wallin's journey to the Wahabi country was planned from the moment he applied for the travelling scholarship of Helsingfors University, which gave him the means to travel in the East. His main objectives were Yemen, to study Himyaritic, and Southern Nejd, neither of which he reached. His two visits to Northern Nejd, both as he hoped on the way to Riyadh, had no political character. His only means during the seven years spent in the East (eighteen months in all in Arabia, long voyages on Arab vessels, short stays in Syria, Persia, and 'Iraq, and the rest in Egypt, chiefly Cairo), were travelling scholarships and a grant from Helsingfors, with perhaps a small loan also from friends in Finland. Wallin's first and longest stay in Cairo was spent in an intensive course of studies to enable him to pass as a Muhammadan in Arabia. He called himself Abdolvali, went native altogether, avoiding European society, except that of a few travellers and of the Russian consulate through which he received remittances and letters. In the very detailed and outspoken diary there is no

trace of any connection with the Turkish official class, only with Arabs of the lower and middle classes.

Fresnel, then on his way home from Jidda, strongly advised Wallin to approach Arabia from Syria or 'Iraq, not Egypt, "on account of the suspicion with which all that comes from Egypt is seen in the Hejaz." Want of means prevented Wallin from following this advice; he had to choose the shortest route, and his reputation as a disinterested explorer has suffered. There was some of the expected gossip in the desert towns: Wallin's Islam seemed unimpeachable, and it was a plausible explanation of the strangeness of this itinerant doctor, who began by refusing to take fees from his patients. But on the first journey the rumour was not taken seriously. He was an honoured guest at Jauf for four months, and spent two months at Hayil, happy and unmolested, glad to see the great 'Abdullah Ibn Rashid, still more glad to avoid making his personal acquaintance. Unrest in the country and want of money prevented his proceeding to Riyadh.

Before the second journey, since passports had come into fashion, Wallin got an ordinary *tedzkere* through his consulate. Unfortunately he applied, also through his consulate, for a general letter of introduction for use in Arabia. This was refused, and the interest of the Egyptian authorities probably aroused. They may have sent warnings to Arabia. Travelling in the spring, when the desert routes were lively, Wallin fell in with a party of 'Abbas Pasha's servants, bringing a string of horses from Hayil to Cairo. A brutal slave accused Wallin, with threats, of calling himself a servant of 'Abbas Pasha—the rumour was another instance of the inexhaustible gossip of the desert towns. Wallin took this very seriously, went to the chief slave, showed his *tedzkere*, and under his eyes wrote an Arabic letter to his friends in Cairo, asking them to deny any reports injurious to his reputation. The friends were a highly connected Wahabi sheikh, who had given him a letter to Riyadh, and his own consulate. The letter reached Cairo, but does not seem to have been completely successful. Soon afterwards Wallin fell in with another horse-coping party, this time Ibn Sa'ud's men, returning to Riyadh from Cairo. With them, as he afterwards realized, was another slave of 'Abbas Pasha. Wallin thought he could have no better companions to Riyadh, and asked if he might join them. They agreed, saying they knew about him. Wallin took this to mean that they had heard of him on the way, but afterwards thought they had been told about him at Cairo. They reached Hayil; there they were told that Ibn Sa'ud was on a *ghazzu*, and as his men decided to go straight to him by forced marches, which gave no opportunity to observe the country, Wallin parted from them. At Hayil the brother of the new Emir sent him a warning on no account to visit Ibn Sa'ud's country, for he was known to be a Christian, and would certainly be killed by sword or poison; the friendly advice was a token of liking and respect. The recognition as a Christian was a great blow; but as it would have been foolhardy to go on to Riyadh, Wallin left Hayil for Baghdad. Not only was Wallin not in Egyptian service; he thought it probable that he had been thwarted, and had nearly run into great danger, by the interference of the Cairo authorities. After further travel and great privation, he made the acquaintance at Baghdad of Major Henry Rawlinson, who showed him great kindness and later introduced him to the Royal Geographical Society.

In his published papers Wallin passed lightly over these occurrences. His aim was to convey as much information as possible about the places visited, not to make an interesting account of his own adventures; besides, he still hoped to visit Riyadh, and doubtless thought reticence advisable. Hogarth notices the abrupt beginning of his account of the first journey (*J.R.G.S.*, vol. 24, 1854, p. 115). Wallin would never think that, writing for a scientific geographical journal, any preliminary justification of a journey of discovery was required.

There are several other points on which the impression left by the two papers is not borne out by the letters and diaries. As to Wallin's geographical work, Hogarth says (*op. cit.*, p. 161): "One reservation, however, must be made: he carried no instruments." Besides medical instruments he did carry watch, compass, and thermometer, but no barometer. An aneroid was practically out of the question at that date. Even these gave rise to suspicion. As originally planned the journeys had a philological rather than a geographical purpose. After the first journey Wallin deeply regretted not having had astronomical instruments or knowing how to use them. "I could have determined the geographical position of the places I stayed at." But probably they were not to be had at Cairo, and he was too poor to buy them. In the plan laid before the Royal Geographical Society and the Russian Geographical Society just before his early death, he asked for astronomical instruments and meant to learn their use, though he pointed out that they would increase the risk of an Arabian journey. He also meant to take lessons in geology and drawing.

It must be said that Hogarth does not reproduce Wallin's views on the trend of the Arabian peninsula, as given in the two papers, quite fairly. Wallin believed in a southerly or south-easterly decline, but stated expressly that 'Iraq and especially Basra are probably the lowest parts of all Asia. This is overlooked by Hogarth (p. 165).

It is said that the Blunts, a generation later, had more sympathy with nomads (Hogarth, *op. cit.*, p. 167). Actually Wallin had an intense appreciation of the desert and nomad life, as countless passages witness, often with beauty. In the '40's this appreciation was a new thing. Neither Burton nor Palgrave can compare with him in that respect. His experience of the Badawin was much shorter than Doughty's, but his instinctive understanding was as great. Most aspects of desert life are described; the customs of travel and hospitality at length; the antique Arabic, with its metallic sounds; the death and burial of a sheikh; womenfolk, to whom he had free access, for the medicine-chest always stood in their part of the tent; children and their upbringing; desert laws, which he hoped later to collect, and the impingement of Koran law on desert law, through the power of the Wahabi princes of Shammar and Riyadh; music, some of which he transcribed and published; the camel language; Badawin domestic economy. In a charming letter to his mother describing desert housekeeping Wallin mentions the excellent butter, saying it was always made from goat's, never from camel's, milk. Palgrave also denied its being made from camel's milk, and has been taken to task for it by Mr. Philby. The Badawin ignorance of their own religion and comparative tolerance are noticed. "I think that even a professing Christian who knew the language and was familiar with Badawin virtues, such as hospitality and manliness, could live among them."

One or two further points call for notice. Hogarth says (p. 167): "Concern-

ing his pilgrimage to Medina and Mecca Wallin has left no detailed narrative." This is true of Medina, not altogether of Mecca; the excursion to Arafat is fully described. He was there against his will, rather bored and anxious, in bad health and longing to leave. Again (p. 168): "Wallin returned to Cairo, and ere he had given any information to Europe about his journey, was back in Arabia." This is only true of published information. He had been careful to send his journal back in instalments to Helsingfors, and wrote many immensely long descriptive letters to some intimate friend at the University, probably Professor Geitlin the Arabist. They were partly meant as informal reports. Some extracts were published in newspapers in Finland. Wallin's records, though he was often obliged to wait for weeks and months before he could contrive privacy enough to write them up, are on a different level from Palgrave's account, which was admittedly written some time after his journey.

Speaking of Wallin's stay at Taima, on the second journey, Hogarth says: " . . . he did not hear, or was not curious enough to inquire of el-Hejr, the place of the mysterious rock-cut houses of the Prophet Sāleh (Medayin Salih), which lay on the road thither." Years before, at Cairo, Fresnel had told him of them; so far they had only been seen by Badawin. On four separate occasions (five if the plan laid before the Russian Geographical Society is counted) Wallin tried to plan his journeys so as to visit Al Hijr; but without success. He was to a great extent at the mercy of chance companionship; the papers in the *Journal of the Royal Geographical Society* give no idea of his constantly changing plans. At Ma'an, on the first journey, he could learn nothing of Madain Salih, and that may have damped his interest. But he never gave up the project, which Doughty was later to carry out.

THE VOYAGE OF LUIS VAEZ DE TORRES

NEW LIGHT ON THE DISCOVERY OF AUSTRALIA, as revealed by the Journal of Don Diego de Prado y Tovar. Edited by Henry N. Stevens. With annotated translations from the Spanish by George F. Barwick. *London: Henry Stevens, Son, and Styles* 1930. (*Also issued as Series* 2, *No.* 64 *of the Publications of the Hakluyt Society.*) 9×6 *inches;* xvi+262 *pages. Facsimile maps*

THE title of this work is unfortunate, for, as we shall see later, it cannot really be said to throw any new light on the discovery of Australia, however much it may do so on the voyage of Torres through the intricate channels to the north of that Continent, on which our information has hitherto been regrettably scanty. But as the editor has chosen to consider the new data in the special connection indicated by the title, we are more or less bound to follow his lead, though this may involve criticism which the book might otherwise have escaped.

Questions of priority of discovery, whether in the realm of Natural Science or Geographical Exploration, are never lacking in interest, and seldom fail to excite discussion and controversy. Regarding geographical discovery few questions of priority have been more discussed and controverted than the discovery of Australia. The claims of the French, Portuguese, Dutch, and Spaniards have all had their advocates. The unbiassed observer would probably come to the

opinion that in none of them is the case conclusively proved. But the weight of the evidence has ruled out the French and Portuguese, thus limiting the controversy to the Dutch and Spaniards, and the problem has contracted to the question which of them first discovered the mainland in the region of Cape York.

A Dutch ship, the *Duifken*, is said to have started from Bantam in 1605, sailed east along the south coast of New Guinea as far as the beginning of Torres Strait, and then turning south reached land on the west coast of Cape York Peninsula somewhere between 13° and 14° south latitude. Such is the story, but no contemporary documentary evidence of the voyage has ever been found. The evidence is indirect, but is nevertheless by no means negligible. References to the voyage are found in the log of the *Pera*, which explored the western coast of Cape York Peninsula in 1623, and in the instructions given to Tasman before starting on his voyage in 1644.

The Spanish claim rests on a more definite basis. In 1606, Torres, in a Spanish ship, discovered and passed through the strait which bears his name. There is documentary evidence of this voyage in a letter written by Torres himself, and two very brief letters by Diego de Prado, a Spanish captain on board his ship. Torres mentions that in the course of the voyage through the strait he sailed as far south as 11°, which is farther south than Cape York. At this point he might well be in sight of the mainland of Australia. But he gives little detail, and was evidently quite unaware of being in the vicinity of the mainland. Hence arises the special interest of the book under review, which for the first time makes known the long-lost manuscript *Relación* of Don Diego de Prado y Tovar, who accompanied de Quiros as first officer on his voyage to the South Seas in 1605–06. As the result of disagreement with de Quiros, de Prado removed to the other ship of the expedition which was under the command of Torres. At the island of Espiritu Santo de Quiros' crew mutinied, and deserting their consort in the night, took the ship to Mexico. In consequence, after waiting some time in hope of the return, or discovery, of de Quiros' ship, Torres opened his sealed orders, and found that in such a contingency as had happened de Prado was appointed commander of the expedition. We have the surprising revelation that the real head of the voyage through the strait was not Torres, but de Prado. Torres became the navigating officer under de Prado. All this we learn from the manuscript *Relación* written by de Prado in his own hand, which gives a very interesting detailed account of the voyage through the strait, and thence to Manila. Whether we agree or not with the Editor in regarding the *Relación* as "undoubtedly the most important find of virgin historical material in modern times," and "the very corner-stone of Australian pioneer history," its importance as a first-hand account of one of the most remarkable voyages made in the Age of Discovery will be disputed by no one.

The Editor whole-heartedly accepts the author's account of his own position and his very low estimate of de Quiros' character and work. In his opinion "de Prado becomes a great captain and discoverer whose name has never yet received due recognition, and he must in future be placed in the ranks of the great navigators, and his name coupled with that of Torres as joint discoverers of Australia." The evidence in support of this statement is not very apparent. There can be little doubt that the very skilful navigation of the strait infested with islands, shoals, and currents was due to the seamanship and ability of Torres. Now it is curious to note that Torres in his letter written in Manila after the voyage does not even mention de Prado's name, and in his account of the contents of the sealed orders opened after the departure of de Quiros' ship says nothing of de Prado being nominated to succeed the command. Further, in the maps of de Prado illustrating the voyage, which have long been known, that officer describes the

regions mapped as having been discovered by Torres, not by himself, and in his second brief letter to the King, written from Goa in 1613, he speaks of the discovery of Magna Margharita (New Guinea) as having been made by Torres. Concerning the discovery of Australia, the highest latitude noted by de Prado is that of the Isla de Perros, which he says is in 10° S. lat., and on which he landed. Torres in his letter says that after going along many leagues of coast a bank of 3 to 9 fathoms was encountered. His actual words then are "we went over it along the coast to 7½°, and the end is in 5 [? fathoms]: we could not go forward owing to the many shoals and great currents which are throughout it, so we had to go out turning south-west in the said depth to 11°, and the bank was lower: there were very large islands, and they seemed to be more on the southern part." These are the only details given by Torres. They are sufficiently vague and tell us practically nothing of the route he took. If he was in 11° S. off the coast of Cape York Peninsula, he would be a considerable distance south of Cape York, and would not see islands to the south. Mr. Stevens tries to get over this difficulty by suggesting that he may have mistaken the mainland for islands.

In this vague and uncertain state we turn to de Prado's account in the hope of enlightenment. He says that after leaving the Isla de Perros they went to an island inhabited by cannibals, and thence to a small island with an abundance of trees. He here gives a date, September 22, on which there was an eclipse. Proceeding after three days they reached a flat island showing evidence of volcanic action, so they called it the Isla de Vulcanquemado. From here they went towards other islands, and in three days reached the largest "which greatly resembled the hill of our lady of Montserrat"; they therefore named it Montserrat. So far it has been plain sailing. But now a critical point is reached. If Torres' 11° S. is correct, they must have continued in a southerly direction. Unfortunately de Prado gives no indication of the direction they took, and no latitudes, and we must draw our inferences from what he says. It is here important to note that at the small island with trees previously mentioned, he makes the significant remark that "we tried again to go to the great land, but the shoals were so large that we could not get across." This shows that they were constantly on the look out for an opening through which they could by a westerly or north-westerly course get back to the south coast of New Guinea. Now the question arises: Did they on leaving Montserrat find such an opening, and go west instead of south? De Prado's account suggests that they did. He says that from Montserrat they sailed in search of other islands, and at the end of three days anchored between two islands to take in water. On the following day they encountered such strong currents that they were unable to make any progress for eight days. At last, when the currents ceased, they passed through a *very narrow channel*. On emerging from this they found, at the end of two days, other islands to the north, one bigger than the rest where they anchored in 5 fathoms, half a league from the shore. As he says this occurred on the eve of St. Francis it is possible to fix the date as October 3. Unfortunately this date instead of helping only makes confusion. It will be noticed that the time between the two dates September 22 and October 3 is eleven days, yet if de Prado's times are added up the time taken must have been at least eighteen. This is sufficiently perplexing and can only be explained on the assumption that de Prado has exaggerated the times taken in going from island to island, or has made a mistake in the dates.*

*Mr. Arthur Jose writes to point out that this difficulty about dates is removed if we recognize that de Prado has made a slip in saying that an eclipse of the moon took place on 22 September 1606. The true date was September 15, so that between this and the eve of St. Francis we do get the eighteen days needed. If, Mr. Jose says, the *relación*

Captain Francis Bayldon of Sydney, who has a very intimate sailing knowledge of the strait, in a recent article in the *Journal of the Australian Historical Society*, a copy of which has been received, has sought to identify the islands mentioned by de Prado and interpret the course he took. He rather strangely identifies the Isla de Perros with Bristow Island, which is not in 10° S. but about 9° 10′. He considers the Isla Vulcanquemado to be Long Island in 10° 2′ S., and believes that Montserrat is Mount Ernest Island, 750 feet high, in 10° 14′, and that it was the nearest approach of Torres to Australia. It certainly agrees better with Torres' remark that there appeared to be more islands to the south. Mount Ernest Island is 27 miles from Cape York, which could not be seen from the ship, though on a clear day the hills in its neighbourhood are visible from the highest point of the island. Accordingly he believes that Torres' 11° S. is a mistake for 10° S. Captain Bayldon interprets de Prado's account after leaving Montserrat Island as showing that they went in a north-westerly direction along the north side of Banks and Mulgrave Islands, and that the very narrow channel passed through was Bligh Channel, through which currents flow at 6 miles an hour. Mr. Logan Jack, as far back as 1921, suggested that Torres' route was through Bligh Channel. The islands to the north, reached after coming out of the channel, Bayldon identifies as Kerr and Deliverance Islands, the latter being the large island where they anchored. It is situated off the south coast of New Guinea in about 9° 40′ S. lat. and 141° 40′ E. long. Assuming he is right in rejecting Torres' 11° S. as a mistake for 10° S., the route he suggests does not appear to be inconsistent with de Prado's account, and would better explain Torres' remark that there were very large islands, and these seemed to be more to the southward.

If, on the other hand, after leaving Montserrat Island the expedition continued south, as it must have done to reach 11° S., it would have passed and probably sighted Prince of Wales Island and Cape York, and gone through Endeavour Strait as Mr. Stevens suggests it did. But that strait is 7 miles wide and cannot have been the very narrow channel referred to by de Prado.

The conclusion cannot be avoided that from the accounts of Torres and de Prado it is impossible to form a clear and altogether satisfactory view of the route followed. But the probabilities distinctly favour the route by Bligh Channel rather than through Endeavour Strait. Of one thing we may be sure, that neither Torres nor de Prado for a moment recognized any land as continental. At most they may have unconsciously sighted it, but there was no landing on it.

Mr. Stevens contends that inasmuch as the islands off the north coast of Australia are now under the Government of Queensland, the discovery of these islands was tantamount to the discovery of Australia, just as the discovery of the West Indian Islands by Columbus is always regarded as the discovery of America. The aptness of the analogy may well be questioned.

Unfortunately the route-map which de Prado in his first Goa letter says he is sending to the King has never been found, and the certificate of truth and accuracy signed by Torres and others which is appended to the *Relación* is a copy in de Prado's handwriting. The original has never been recovered. De Prado's part in the expedition depends therefore wholly on his own statements. Moreover the copy of the *Relación* now brought to light must have been written long after the voyage, for he describes himself therein as a monk of the order of St. Basil of

had really been a journal, such blundering would have been impossible. But if it is an account compiled many years later from de Prado's travel stories (or even from his dictation) the error in dating is natural: "22" is due to a slip of memory in confusing this with the previous eclipse, which did take place on March 22 (see p. 107).—Ed. *G.J.*

Madrid, which he became only after his return from Goa in 1615. The certificate is curiously enough dated June 1608, although the voyage ended at Manila in May 1607.

It is impossible not to discern in de Prado's *Relación* and letters a very strong animus against de Quiros, though Sir Clements Markham's description of him as a malignant enemy of de Quiros, and a mutinous officer, may be exaggerations. But if the statements in the *Relación* regarding de Quiros' conduct of the expedition are true, de Prado had good grounds for distrusting him, and for accusing him both of not following the directions given him by the Viceroy, and of not showing proper concern for the welfare of his crew. On the other hand, there is much in the account of the voyage before the separation, and in that of his navigation of the *Capitana* to Manila after the mutiny and disasters at Santa Cruz during Mendaña's second voyage, of which he was the pilot, which supports Sir Clements' estimate of de Quiros as being "averse to violence and bloodshed, a zealous Catholic, striving to maintain religious feelings and to enforce morality. Brave and resolute himself, full of zeal and enthusiasm, he failed in the management of men. He was weak and vacillating, and had not the force of will necessary to control the turbulent and to cheer the half-hearted."

The most serious charge against de Quiros is that after the separation he disregarded his instructions, which were that in such an event the ships were to make for and meet at Manila. If de Prado's reference to the mutiny, which he says he learnt later from members of the crew, correctly represents what occurred, de Quiros was kept a prisoner in his cabin, and would not therefore be in a position to carry out his instructions. But in the account of the return of the ship to Mexico, believed to have been written by de Quiros' secretary under his inspiration, there is no corroboration of this story, and it appears that he agreed as a matter of expediency to return at once to Acapulco.

Therefore, whilst recognizing to the full the great interest and importance of the *Relación* in giving a first-hand detailed account of a great voyage, and the discovery of Torres Strait, we are inclined to the conclusion that it tells us little more than was previously known regarding the discovery of Australia.

Although our knowledge of the voyage of the *Duifken* is only secondhand, yet considering the sources from which it comes, the probability is high that it is trustworthy, and that consequently the York Peninsula was not only sighted, but touched at by the Dutch before Torres passed through the strait. If in so doing any of the crew landed on the coast, the Dutch must have been the first to set foot on the Island Continent. On the other hand, if the neighbouring islands of Northern Australia are to be regarded as part of that continent, then the landing of de Prado on the Isla de Perros in 10° S. lat. would give the discovery, so far as it rests on direct evidence, to Spain.

The volume is well printed and illustrated with maps. All the Spanish documents have been newly translated by Mr. G. F. Barwick, and the Spanish text and the translation of the *Relación* are given on opposite pages.

E. A. PARKYN

THE *ITALIA* DISASTER

L'*ITALIA* AL POLO NORD. By UMBERTO NOBILE. *Verona: A. Mondadori* 1930 (3rd edition). 10×7 *inches;* xvi+476 *pages; illustrations and maps. Lire* 40

WITH THE *ITALIA* TO THE NORTH POLE. By UMBERTO NOBILE. English translation by FRANK FLEETWOOD. *London: George Allen & Unwin* 1930. 9×6 *inches;* 358 *pages; illustrations and maps.* 15*s*

THE POLAR ADVENTURE: the *Italia* tragedy seen at close quarters. By ODD ARNESEN. Translated from the Norwegian by Asta and Rowland Kennedy. *London: Victor Gollancz* 1929. 10×6 *inches;* 158 *pages; and illustrations.* 12*s* 6*d*

SIEBEN WOCHEN AUF DER EISSCHOLLE: der Untergang der Nobile-Expedition. By FRANZ BĚHOUNEK. *Leipzig: F. A. Brockhaus* 1929. 8×5 *inches;* 264 *pages; and illustrations. Marks* 7

DEPRIVED of his rank as General and condemned by a Court of Enquiry for faulty dispositions, as well as for an error of judgment in allowing himself to be rescued before his companions, Signor Nobile writes as a man with a grievance, and it is no part of a scientific journal to deal with this aspect of the affair. But there are many other aspects of great interest and some importance, and we welcome the English translation of the handsomely produced Italian volume, though the illustrations have been so much cut down and the price is fifteen shillings against the Italian forty lire. The translation seems to be well done, except for mistakes in technical terms; but it appears to have been made from a version of the Italian not quite the same as that published.

We have now a detailed account of the disaster which befell the *Italia* on her return from the Pole. The strong favouring gale which had taken her there so speedily from the north coast of Greenland had given her commander doubt and hesitation for the return, and he had seriously contemplated making for the mouth of the Mackenzie River instead of trying to fight his way back against the gale to King's Bay; but Malmgren had dissuaded him, and they set out on the return journey at 2.20 a.m. on May 24 along the meridian of 25° E. Soon the sun clouded over and it was necessary to descend below the fog to sight the ice and obtain observations for drift and speed over the ground; the former proved to be large and the latter disappointingly small. Much ice formed on the ship, and fragments thrown off from the propellers tore little rifts in the outer envelope which were promptly repaired. Soon there was doubt as to the position of the ship, the only guide being radio-gonometric bearings from the *Città di Milano* which gave a rough line of bearings but of course not the position on that line.

At 7 a.m. on the 25th they should have sighted the north coast of Spitsbergen, but there was nothing to be seen, and at 9.15 the elevator helm jammed* while the ship was on a downward slant. The engines were stopped and the ship soon rose above the fog into strong sunlight, which with the radio bearing gave them a position 180 miles N.E. of King's Bay. The elevator was repaired and they descended again into the fog. At 10 they were sailing at a height of 200 to 300 metres, with the ship light and the nose a little depressed to counteract it: or as the translator has it, "a bit of a list to bow." At 10.30 the chief engineer reported that the ship was heavy; she was down by the stern and falling rapidly. A man was sent to inspect the stern valves, and the engines were accelerated; the ship was then 15° to 20° down by the stern, and the increased speed should have taken

*Běhounek says that owing to an error of the man at the control it became stuck at the "dead point"; but his account is hard to reconcile in detail with Nobile's.

her up, but she continued to fall; orders were given to stop the engines, and she crashed at 10.33, carrying away first the stern-motor gondola, in which Pomella was killed, and then the pilot cabin.

Signor Nobile records at some length the discussions which they had during their sojourn in the red tent on the possible causes of the disaster, and comes to no conclusion, but thinks it possible that a steel tube in the stern may have fractured and pierced the gas-bag there. The loss of buoyancy may have been due also in part to accumulation of ice; but the ship had been light not many minutes before, and a burst at the stern seems to be the probable cause.

The pilot cabin was torn away, excepting its wall on the port side, and the inmates and contents were scattered over the floe. None were killed, and only two severely injured; five of them were able to stand at once, practically unhurt. And what is more remarkable, many of the instruments were undamaged. The field radio station was got to work almost immediately; the sextants and even the chronometers survived. There was a scanty selection of every requisite store, a tent, a sleeping bag, petrol, matches, a revolver and cartridges, a Very pistol, and 70 kilograms of provisions. Very fortunately one of the two bags packed with requisites for a landing party had been thrown out, which explains the almost incredible completeness of the outfit with which the nine men faced life on the pack. Of the six who were carried off with the ship nothing was ever heard, and all that Nobile can say of their fate is that he does not think they can have drifted more than 20 or 30 kilometres. If it should seem that in that case they ought to have been seen by the searching aeroplanes, one must remember that it proved very hard to see from the air objects confused by the strong shadows of the broken pack, and that the tent party were not found until they could direct the search by wireless.

The most instructive part of the whole extraordinary story is the success and the maddening exasperation of the wireless communications. Within a few hours of the crash Biagi was sending and receiving. Almost at once they began to hear the San Paolo station near Rome announcing anxiety at their non-return, and day by day they learned of the tremendous concentration of relief ships and aeroplanes. They could hear also all the messages from the *Città di Milano* both to them and to Rome, and they knew that the search was being directed to the wrong place, but could not make the base ship hear them. The party on the ice came to believe that the ship was not listening for them, but this seems to be refuted by the account of Mr. Odd Arnesen. However that may be, it is admitted that the first to receive their signals was a Russian amateur at Archangel to whom all credit is due for his effective action. On the evening of June 6 Biagi read in the San Paolo evening bulletin: "The Soviet Embassy has informed the Italian Government . . ." of the mutilated message received by Schmidt on June 3. Next morning they heard the base ship sending them a message, but thought it was for Rome; in the evening they learned from San Paolo that an American amateur had intercepted a message from them giving their latitude as 84°, and this thoroughly upset them. But a little later they heard Press messages from King's Bay saying that the *Città* had received some fragments of their continual call and that they were believed to be in Franz Josef Land—a curious error due to the receipt of the words "Foyn circa" as "Francesco." And at last next evening they received from Rome the news that the base ship had heard them well that morning, and proposed to call them at the fiftieth minute of every hour on 900 metres, whereas they could receive only on 32. However a system was evolved gradually which gave direct communication between the camp and the ship. Every two hours, declares Nobile, the *Città* called them: "We have nothing new to tell you. Good-bye till the next hour," and switched over to San Paolo without waiting a

moment to see if the ice-party had anything to tell them. "These words coming so clearly to our ears every two hours seemed almost like mockery." With this slight hint of the recrimination which plays a sadly large part in the book we should stop; for much of what follows is most interesting, but painful reading.

In the earlier chapters Signor Nobile gives a careful account of all the scientific preparations: oceanography, sounding, magnetism, atmospheric electricity, radio-activity, gravity survey were all included in the programme, and the author writes of them with knowledge and discernment. The results that were saved have been discussed by Běhounek in a supplement to *Petermann*, and require separate notice. But it is curious that Nobile says nothing anywhere of the methods of navigation by sun-sights. We do not know whether Commanders Mariano and Zappi used the method of position lines which was found so effective by Byrd and by Wilkins, nor what type of sextant they employed, nor what effect the crash had on the rates of the three chronometers which were picked up all going, nor whether the daily longitudes of the drifting tent were controlled by time signals from one of the principal sending stations.

Not on these, but on other instrumental questions the clear and restrained narrative of Dr. Běhounek throws some light. One would have gathered from Nobile's narrative that when Malmgren, who was steering, threw up the wheel and the General seized it, he failed in his effort to direct the fall to a field of snow, and that they crashed on ice. But it seems that he may have been more fortunate than he supposed, for Běhounek is quite definite that they fell on snow. He describes how snow was forced into the fragile pilot-gondola, and how he and others were buried in snow and had to extricate themselves, after they had been dragged 50 metres. The gondola sides were only linen. The snow seems to have burst them in and scooped out the contents, and this must be the reason why chronometers and radio-valves in their cartons, accumulators and dry batteries, sending and receiving sets, sextants and apparatus for the study of atmospheric electricity all survived more or less in working order, while of nine men only two were badly hurt. It is important in explaining the otherwise incredible.

The book of Odd Arnesen supplies picturesque details, and gives a good account of the difficulty the airmen had in spotting the parties on the ice; but in the main it is the plaint of a Norwegian journalist who thought little of the Italians, mocked at their ice-craft, disliked the appearance of the base-ship and kept on saying so, continually pestered its commander, but had often to fall back on "padding about wind and weather, about chances and possibilities," which is not a bad description of his book. "It was not all honey being a pressman in those days in New Aalesund," but the reader's sympathy will go rather to Commandant Manoya than to the importunate crowd that besieged him and complained.

Read with the excellent book of Giudici, who saw events from the *Krassin* (see *G.J.* 73, 1929, pp. 68–71), these three accounts from very different angles give us now ample if incomplete material by which to judge the heroic, disastrous, confused, and controversial episodes of the *Italia's* voyage to the Pole. The story should be read carefully and pondered deeply, for it has many lessons for the future.

REVIEWS

DIE HÄFEN ENGLANDS: eine wirtschaftsgeographische Untersuchung der Schiffahrtszentren in Groszbritanien. By J. H. SCHULTZE. *Leipzig: Deutsche Wissenschaftliche Buchhandlung* 1930. 9×6 *inches;* 178 *pages; illustrations and maps. M.*14

Dr. Schultze claims that the chief contribution of this book to the literature of the economic geography of ports is to be found in its method. Numerous footnote references and an appendix containing an extensive bibliography indicate the width of the literature consulted, but the tone of the book is evidently set by the impressions gained by the author during a tour of the chief ports in 1927. Briefly, his thesis is that ports have a recognizable "physiognomy" in their lay-out, equipment, and organization; that this physiognomy is in harmony with the type of traffic they handle; and that the type of traffic depends in turn on the nature of the hinterland and in a minor degree on the nature of the overseas lands with which they have regular contact. Site factors, he considers, have lost almost all their earlier importance: Southampton and Scapa Flow alone of the ports of Britain owe practically nothing to dredging. Similarly, since the industrial and commercial revolutions of the eighteenth and nineteenth centuries and the growth of a multiplicity of direct shipping services, world situation of any particular port is of decreasing importance. The hinterland, then, is dominant in determining the character and amount of the trade of a port, and therefore its physiognomy, so that ports can be classified on the basis of the nature of their hinterland. His classification for Britain is as follows: (1) Ports serving densely populated regions: *a*. Cargo ports (*e.g.* London). *b*. Ports dealing with rapid traffic (Southampton, Grimsby and the ferry ports). (2) Ports serving industrial regions (Liverpool, Hull, etc.). (3) Ports serving coal fields (Tyne and South Wales ports). (4) Ports serving the whole country (naval bases).

This thesis is worked out in a detailed study of the ports of London, Southampton, the ferry ports, Grimsby, Liverpool, Manchester, Glasgow, Bristol, Hull, the Tyne, and Cardiff—an admirable analysis of the varying effects of the geographical, historical, and economic factors, supplemented by maps, statistical tables, and some excellent photographs. Concluding chapters devoted mainly to the delimitation of hinterlands and of "Überseelander" necessarily involve a good deal of repetition, and are, apart from that, the least satisfactory portion of the book.

From the point of view of the method of treatment, the reviewer does not share Dr. Schultze's estimate of the value of his work. His specific classification and especially his insistence on port physiognomy are certainly new, but they represent rather a refinement of what has been expressed and implied in the usual English classification of ports into general and specialized, than a completely new conception. This however is not to deny the worth of the book, of which the worst that can be said is that the concluding chapters are less good than the rest. An English translation would be a welcome addition to our literature on the subject. R. O. B.

A HISTORY OF IBERIAN CIVILIZATION. By J. P. DE OLIVEIRA MARTINS. Translated by AUBREY F. G. BELL. With a Preface by S. DE MADARIAGA. *Oxford: University Press* 1930. 9×6 *inches;* xx+292 *pages.* 12*s* 6*d*

Oliveira Martins, a self-educated man who wrote history in the leisure hours of an active life as engineer, financier, and politician, died in 1894 at the age of forty-nine. His sketch of the political and spiritual evolution of the Iberian peoples, which has recently been published in a Spanish, and now in an English, transla-

tion, had appeared fifteen years earlier. Obviously the date and circumstances suggest that the permanent objective value of the work is but slight, and it is unfortunate that this *a priori* impression should appear to be so abundantly confirmed, for readers of this *Journal* at least, in the opening pages dealing with "The Country." The content of these pages is, however, irrelevant to the argument of a work whose theme is stated explicitly to be an "Iberian unity transcending these (the geographical) differences" and "the ethnological variations which they conserve," while the new relevant material of to-day fits often surprisingly well into the author's sketchy framework. Of this Iberian unity Oliveira Martins is claimed by Professor de Madariaga, in a prefatory note to the volume under review, as the first exponent. More important than the priority of his vision is its potency as a stimulant, and it is this which principally justifies the present publication, for which the Oxford Professor of Spanish Studies stands sponsor, in spite of the misgivings expressed in the preface and in the translator's introductory essay. The reader will probably feel more gratitude to Mr. Aubrey Bell as author of this essay than as translator. R. A.

BAEDEKER'S HANDBOOKS FOR TRAVELLERS

NORTHERN ITALY, including Ravenna, Florence, and Pisa. (Fifteenth Edition.) 1930. lxxxii+704 *pages*. 16*s*. ROME AND CENTRAL ITALY. (Sixteenth Edition.) 1930. lxxiv, 586+24 *pages*. 16*s*. SOUTHERN ITALY AND SICILY, with excursions to Sardinia, Malta, Tripoli, and Corfu. (Seventeenth Edition.) 1930. lxxx+552 *pages*. 16*s*. ITALY FROM THE ALPS TO NAPLES. Abridged Handbook for Travellers. (Third Edition.) 1928. xxxviii+488 *pages*. 13*s*. By KARL BAEDEKER. *Leipzig: Karl Baedeker*. 6×4 *inches; maps and plans*

MUIRHEAD'S BLUE GUIDES

SOUTHERN ITALY, including Rome, Sicily, and Sardinia. By L. V. BERTARELLI. Edited by FINDLAY MUIRHEAD. *London: Macmillan & Co.* (*Second Edition.*) 1930. 6×4 *inches;* lxxii+538+[26] *pages; maps and plans*. 15*s*

The appearance of a new edition of the three volumes of Baedeker's admirable guide to Italy, as well as of the single volume on Italy from the Alps to Naples, at the same time as a new issue of Muirhead's Southern Italy, must be something of an event to travellers south of the Alps. To many such travellers the chief additional value of these books will be the fact that, owing to the stabilization of the lira, it is once again possible to include the prices of things and especially of hotels. It is a pity that Muirhead has not always troubled to give the prices of *pensions*, as at Naples. Travellers who can afford good hotels can easily obtain all the information they want, but their less fortunate brethren find it almost impossible to get details of good *pensions* even at the national agencies. Baedeker, indeed, is so impeccable in his thoroughness that it is a pleasure to be able to inform him that the church of Sant' Agostino at S. Gimignano has now been restored to the Austin friars. He describes even the air-routes in detail, with prices. The volume on Northern Italy now contains the new provinces, that on Southern Italy includes Tripoli, with excursions outside Italian territory to Malta and Corfu. Another feature of Baedeker, which our English guide might well imitate, is the list of English books which may prove useful to travellers likely to make a long stay in the most important towns. But why is Rome not similarly treated? Baedeker deals with Italy in one or in three volumes, whereas Muirhead covers it in two. Naturally a book which, like the Blue Guide, contains Rome and Sicily, as well as the South, is a great boon. As is well known, Muirhead has to divide his honours with the Italian Touring Club, and this is not altogether an unmixed

blessing. The style sometimes betrays the translation. Why not egg-plant, for instance, instead of *aubergine?* The list of dishes peculiar to the various provinces and towns is excellent, but we are not sure that Baedeker's glossary of ordinary Italian menu terms will not be more useful to the average traveller. Muirhead however is a better friend to the motorist in his glossary of terms and advice about lights, though he does not inform them, like Baedeker, that they are now under the protection of S. Francesca Romana. The only reference to politics is Baedeker's warning that all newspapers are now Fascist. The maps and the information, so far as we can gather, have been brought thoroughly up to date and the hotel prices tally almost to a lira with those charged the reviewer on a recent trip.

L. C.-M.

THE LITTLE ENTENTE. By ROBERT MACHRAY. *London: George Allen & Unwin* 1929. 9×6 *inches;* 394 *pages;* 10 *portraits and a map.* 12*s* 6*d*

The earlier part of this very careful work is the most interesting, for it shows how Western Europe gradually realized the existence of nationalities other than German and Magyar in the Austro-Hungarian Empire and the meaning of the new map of Europe created by the Peace Treaties. The author believes that the immense importance of the latter to the new countries is perhaps hardly realized here now and states moreover that demands made by irresponsible newspapers for alterations in geographical boundaries cause the utmost alarm in the Succession States. The maintenance of the Peace Treaties is the first object of the Little Entente, which however desires to live on friendly terms with all neighbours and to stretch out helping hands to former enemies. Among personalities the figure of Masaryk stands out pre-eminently from the beginning, while it is clear that not only Czechoslovakia but Romania and Yugoslavia also owe a considerable debt to his indefatigable lieutenant, Beneš. We become familiar with many other statesmen in this book, which is really a history of Central Europe since the War and has a political rather than a geographical importance. A large part of it is occupied with a bewildering series of treaties and discussions which make somewhat tedious reading but should be of the greatest value to students of post-War foreign politics. The author appears to take an optimistic view of the future, apart from the Soviet menace ever present in the background.

J. H. R.

A BIBLIOGRAPHY OF PERSIA. By SIR ARNOLD WILSON, K.C.I.E. *Oxford: Clarendon Press* 1930. 10×7 *inches;* x+253 *pages.* 20*s*

In the introduction to his 'Persia and the Persian Question,' Lord Curzon stated his intention of publishing later a supplementary volume containing, among other material, a 'Bibliography of Persian History, Geography, and Travel.' The pressure of his public duties seems to have prevented him from carrying out this project, and the present volume, compiled by Sir Arnold Wilson and Mr. H. W. Mardon, is the first comprehensive bibliography of Persia to appear, apart from a few catalogues of special collections. The first volume of Lord Curzon's work however contains a useful table of travellers in Persia, whose works were originally written, or subsequently translated, in a European tongue. The late Mr. A. P. H. Hotz, who presented his extensive library of works on Persia and the Near East to the Society, was anxious that this gift should promote the publication of a complete bibliography of these regions. He would have been gratified to know that his collection has contributed essentially to the completeness of Sir Arnold Wilson's work, though this does not relieve the Society of responsibility for promoting a more extensive work when time and means allow.

This 'Bibliography of Persia,' which contains about five thousand entries, is arranged in a single alphabet under the names of authors: it is hoped to issue an analytical subject index later. The entries include original works in European

tongues relating to Persia, standard translations of Persian authors, and, to a more limited extent, bibliographies on Persian literature and religions. No attempt has been made to include works in Persian. As acknowledged in the introduction, the bibliographies of early travellers are not complete, apparently only those editions coming under the notice of the compilers being entered. For example, several editions of Marco Polo are given, but not the important edition of Professor Benedetto published in 1928. It may also be noted that several names in the list of travellers which, as mentioned above, was compiled by Lord Curzon, are not to be found in this bibliography. Mejov's 'Bibliographia Asiatica' might have found a place.

The titles have been kept as short as possible, and other details reduced to a minimum, but this does not interfere to any extent with the usefulness of the compilation. One or two slight inconsistencies in the arrangement and description of works might have been avoided. There are a few misprints to be corrected: Richard Willes appears as "Walles" (pp. 65 and 239); and "Hemmy" should read Hemm (p. 94). The title of Hugounet's work should read 'La *poste* des califes et la poste du Shah.' Apart from these minor points the work has been done comprehensively and accurately: with the promised subject index it will form a useful guide to the study of Persia.

HANDBOOK OF THE STATE OF NORTH BORNEO: With a Supplement of Statistical and other Useful Information. *London: The British North Borneo (Chartered) Company* 1929. 9×6 *inches;* 142 *pages; illustrations and a map.* 2*s*

The last handbook issued by the British North Borneo Company was published in 1921; in the present issue obsolete matter has been eliminated and the whole has been rearranged, revised, and brought up to date; an index has been provided and the statistical details include nearly forty pages of useful and reliable information. The result is a work of reference which, having been prepared by authority, can be relied on for its accuracy and contains information which is not available elsewhere. Within its limits also the handbook is comprehensive, for, besides an historical and geographical sketch, it gives details concerning the climate, population, communications, administration, agriculture, timber, minerals, and the principal towns, together with some useful notes for those who intend to visit or to reside in the Territory. O. R.

THE GEOLOGY OF THE KALGAN AREA. By GEORGE B. BARBOUR. (*Memoirs of the Geological Survey of China*, Series A, Number 6.) *Peking* 1929. 10×7 *inches;* xii+148 *pages; illustrations, diagrams, and maps.*

Kalgan lies about 100 miles north-west of Peking, upon the old trade route to Siberia. It stands at a gate in the outer wall which, in this part of the country, lies to the north of the Great Wall proper, and the significance of its position is well brought out by Professor Barbour in his introduction.

Although geology is the main subject there is much in the volume to interest geographers who are not geologists. With the help of a self-explanatory diagram of the geological column, block-diagrams, photographs, and other illustrations, the author has made it very easy to see the relation of the present relief to the geological structure and to follow his account of the evolution of that relief.

The stratigraphical succession in this region is very incomplete. Two pre-Cambrian systems are represented, with an intervening unconformity, but the whole of the Palaeozoic and the lower part of the Mesozoic are absent. The pre-Cambrian rocks are directly followed by a volcanic series overlaid by conglomerates and sandstones, referred by Professor Barbour to the Lower Cretaceous, though the volcanic series may perhaps be Jurassic. Then comes another gap, but

from the Oligocene onwards the succession is practically complete. The Loess is the formation of most general interest. It is of Pleistocene age and mainly of aeolian origin, as Richthofen long ago suggested.

The stratigraphical account is followed by chapters on the history of earth-movements in the area, the general geological history and evolution of the present land surface, and on economic geology. It is the chapter on the evolution of the present land surface that will most interest the non-geological reader. Professor Barbour's exposition is remarkably clear. P. L.

MY TROPICAL AIR CASTLE: Nature Studies in Panama. By FRANK M. CHAPMAN. *London and New York: D. Appleton & Co.* 1930. 9×6 *inches;* xiv+416 *pages; and illustrations.* 21*s*

Nothing can make a naturalist more humble than a brief acquaintance with some tropical forest. All around him is a riotous wealth of life of which little or nothing is known. Even the mere cataloguing of the different kinds, that first step in biological inquiry, is still far, and very far, from being complete. And anything that lies a little deeper than that, for instance the intimate habits of the animals, their mode of growth, their times of procreation, their food, their enemies, their defences, their courtships, is for the most part completely unknown. The field is so vast and the complexity so endless that centuries of study will fail to exhaust it.

But now and then a book appears which illuminates some corner in this vast theme, taking, as it were, a single drop out of the illimitable ocean. Mr. Chapman's work is in this class. It is a study of tropical life in the island of Barro Colorado, a nature sanctuary in the Panama canal. The title of the book is likely to be misleading. His air castle is not on a tree-top, nor even on the summit of a high hill. It is a metaphorical castle in the air, a little dwelling, permanent, delightful, secluded, where the author, surrounded by tropical luxuriance, could peacefully pursue his nature studies in a home of his heart's desire.

Slowly and patiently he observes and records, and brings to light a crowd of facts from the endless maze of forest life. We learn how the birds call in the daylight, and how at sunset they bring it to a close, how the oropendolas make their pendent cradles, how they court and squabble, and battle with their enemies, how they are imposed on by the cuckoo-like cowbirds and evicted by diminutive flycatchers from their homes. There are intimate observations on the nesting of cotingas, on the power of the turkey-buzzard to smell out the carcass, on the skippings and dancings of monkeys through the canopy, on the zonation of life in the forest, and the relation of patterns of colour to the different kinds of haunts. These and many other kindred subjects are discussed in a pleasing simple way. A chapter is given to flashlight photography, and some of the representations of forest animals illustrate the author's conspicuous success. Mr. Chapman's reputation is well known and will be further increased by this new work, a model of careful and patient observation, delightfully and often humorously recorded.
R. W. G. H.

THE ISTHMIAN HIGHWAY: a review of the problems of the Caribbean. By HUGH GORDON MILLER. *New York: The Macmillan Company* 1929. 9×6 *inches;* xiv+327 *pages; and illustrations.* 18*s*

This clearly written study is largely concerned with the status of the Panama Canal in international law, from the points of view of the *de facto* sovereign, the United States, the *de jure* sovereigns of Colombia, Panama, and Nicaragua, and the rights of other nations. The author's main thesis is that the United States possesses a "mandate" for the canal on behalf of the world, and that this mandate

is being exercised with due regard to the welfare of the *de jure* sovereigns and to the fundamental interests of the United States. He desires the Canal to be placed on a sound financial basis, including adequate provision for the capital sunk in it, and is opposed to discriminating tolls or to the application of profits to the relief of United States taxation. (Under the present financial regime, discriminating tolls were abolished by President Wilson's action in 1914.) Wider issues are also involved, particularly American foreign policy and the Monroe Doctrine, which he regards as applying now to the Caribbean alone, and with which the Canal policy stands or falls. He writes of these questions from the American point of view, but with an obvious desire for fairness, and pays particular tribute to the share of Canning in the evolution of the Doctrine, regarding him, in fact, as its virtual initiator. His book is certainly to be recommended to all students of Anglo-American relations.

DIARY AND LETTERS OF ADMIRAL SIR C. H. FREMANTLE, G.C.B., relating to the Founding of the Colony of Western Australia, 1829. Edited by LORD COTTESLOE. *London and Aylesbury: Hazell, Watson & Viney Ltd.* (Printed for Private Circulation) 1928. 9 × 6 *inches; 94 pages; portrait and map*

The exact function allotted to Captain (as he then was) Fremantle in the British occupation of Western Australia has for many years been disputed, some historians claiming that his hoisting of the flag at the mouth of Swan River was the first definite act of annexation, others alleging that the country was already British by virtue of Edmund Lockyer's flag-hoisting at King George's Sound early in 1827. The documents which Lord Cottesloe reprints as a quasi-preface to Fremantle's Diary (though he does not stress that aspect of them) make it clear that until the formal annexation on 2 May 1829 Australia west of 129° E. long. was not considered by the authorities in London to be part of the Empire. Governor Darling, of New South Wales, who sent Lockyer to King George's Sound, certainly ordered him to tell any French visitors that "the whole of New Holland is subject to His Britannic Majesty's Government"; but of his superiors at home Earl Bathurst hesitated, his successor Huskisson flatly refused to accept Darling's view, and the next minister, Sir George Murray, came to the conclusion that Lockyer's action had been limited to the King George's Sound region.

This being so, it is interesting to note that Fremantle himself thought the actual annexation scarcely worth mentioning. In his official letter to the Admiralty (dated Trincomalee, 8 October 1829) he states that on May 2 the flag was hoisted on the south head of the Swan River and possession was formally taken. But in his private diary of that day's events there is not a word to indicate any such action. He "landed to ascertain the best passage," got his boats across the bar with some difficulty, had a meal, and went off upstream. Never was an annexation taken so casually; one begins to wonder whether it happened at all.

Fremantle, it is clear, was far more interested in exploration than in annexation. He had the born explorer's gift of close and accurate observation, and exercised it to the full. Indeed, but for Stirling's exactly opposite quality, an unobservant and optimistic enthusiasm, there might have been no Swan River Colony. Where Stirling created from his own optimism an excellent harbour, a fertile soil, a teeming water-supply, a "land out of all that I have seen in various quarters of the world that possesses the greatest natural attractions," Fremantle noted for the most part doubtful anchorages, dangerous channels, rocky and sandy soil, lack of water everywhere. (These vague phrases do not fairly represent his notes, which are detailed and exact.) Nor was there any bias in his criticism; he noted also what good points there were, and on his return to the colony recorded with pleasure that farther inland there was good wheat country and

plenty of water. Another quality he had, rarer in explorers and, too, in most settlers of young Australia, was enough imagination to comprehend the aboriginal point of view when their hunting-grounds were occupied by uninvited strangers.

To make the diary quite intelligible and to emphasize Fremantle's difficulties and the value of his work, it would be well, if this book is ever prepared for publication, to replace the sketch-map on p. 8 with a reproduction of the corresponding Admiralty chart. The soundings, the reefs, the intricate channels need showing; the impression of deep water and open ocean given by the map is wholly misleading. A. J.

DISCOVERY REPORTS. Volume 1, in six parts. Issued by the *Discovery* Committee, Colonial Office, London, on behalf of the Government of the Dependencies of the Falkland Islands. *Cambridge: University Press* 1929. 13 × 10 *inches;* xiii + 592 *pages; illustrations and maps.* 73*s*

One of the chief difficulties that has confronted the leaders of modern expeditions has usually been the problem of the proper publication of the scientific results which form no small part of the harvest of each expedition.

The record of the *Challenger* Expedition is one of the most complete because of the discovery and exploitation by its leader, Sir John Murray, of the phosphate deposits of the South Sea Islands. That of Scott's Last Expedition was undoubtedly saved from disastrous abbreviation by the national response which followed an appeal for help launched under peculiarly dramatic circumstances. Most other expeditions—the scientific observations of some at least of which were as worthy of record—have been less fortunate. Outstanding examples are the *Scotia*, *Nimrod*, and *Endurance* expeditions.

The present *Discovery* Expedition is unique in at least one sense. For the first time a great polar expedition has been financed directly through the proceeds of an industry which owed its inception to the reports of previous polar explorers. In the single season 1928–29 the output of whale oil alone in one single field—and whale oil is only one of several products of modern whaling—was valued at over five and a half million pounds. A very small tax on such an annual production suffices not only to permit of a thorough survey of the circumpolar seas, but also serves to make certain that the results of such a survey are efficiently worked up and adequately published and disseminated. The first results of this are to be seen in the volume at present under review.

The first section of the Report consists of a list of oceanographical stations the length of which is proof enough of the scope of the work of the expedition. More interesting to the geographical reader is the short and succinct account which follows in the second section of Investigations, Objects, Equipment, and Methods. As the author of this portion, Dr. Kemp, the Director of Research of the Expedition, justly observes, far too little space has been given in the publications of previous expeditions to a description of equipment and methods, for there is no part of an expedition's records from which its successors can glean more of value.

The interesting account of the reconditioning of the *Discovery* recalls to memory the history of the ship. Built at great expense for the National Antarctic Expedition 1901–04; sold much below her value immediately afterwards to the Hudson's Bay Company; out of action completely during one of the most active periods of polar exploration before and during the early years of the War; rotting as a store hulk when she would have been of the greatest value had she been retained as the *Fram* was by Norway; she had finally to be reconditioned at a cost approximating to her original cost of construction. Her history is a good example of the cost of lack of vision and ordered policy in exploration.

The third section of the Memoir, by L. H. Matthews, comprises a short but

interesting account of Antarctic seals, particularly of the elephant seal (*Mirounga leonina*), known more familiarly to the explorer and his reading public as the sea elephant. The account is interesting and the illustrations striking. The occurrence among the best of the latter of photographs taken by the *Endurance* Expedition is another tribute to the excellence of the photography of recent Antarctic expeditions. A study of recent polar narratives would have enabled the author to supplement considerably the short description of the life history of the Weddell seal and sea leopard, the former of which is of course much more common along the truly Antarctic coast-lines than in the seas examined by the *Discovery*. The account of the former has here, perhaps unfortunately, been deliberately restricted to the observations made in South Georgia. The short paragraph on the history of the fur seal affords a drastic commentary on Man's uncontrolled destruction of the assets placed at his disposal by Nature.

The fourth section, by N. A. Mackintosh and J. F. G. Wheeler, with a short chapter on parasites in the following section by Dr. Baylis, includes some 250 pages of text and 20 plates, and is devoted to the first series of observations on the blue and fin whales, the study of which was the main objective of the expedition. The observations recorded range over such diverse subjects as the anatomy, ages, and stock of whales; their food, breeding, and growth; the composition of whales' milk; parasites, both external and internal; the oil content of blubber, and many other problems of economic and scientific importance, but they are naturally of somewhat less interest to the general geographical reader than other portions of the book. Very large numbers of observations have been carefully collated, and as a result tentative hypotheses are suggested or confirmed. Our knowledge of these whales, their habits and their habitat, has been put on a much more systematic basis, although much more information is required before final conclusions of ocean-wide application can be drawn with any safety.

The kernel of the whole of this section of the Report is found on pp. 463 to 469. Of particular importance appears to be the conclusion that whaling in temperate and sub-tropical waters is economically extravagant. If this, and other conclusions the expedition results may later lead to, can be driven home to the whaling industry and whaling regulated accordingly, it is likely that the expedition will soon have more than justified its existence from the economic point of view. There can of course be no question of its scientific value.

Elsewhere in the Report, however, it is shown that under modern conditions control cannot be expected closely to follow upon investigation. The reader forms the opinion that permanent damage may be done before the cumbrous international machinery can be brought to bear to enforce rules formulated as the result of a scientific investigation of the environment of the whale. The survey itself will of course require several more years' work for its completion.

The sixth section, by L. H. Matthews, is a very complete and well-illustrated account of the birds of South Georgia, a subject which, as the bibliography shows, has already been treated by several scientific authors. The records of these earlier investigators have been utilized and are amply acknowledged, and the present account will be useful as bringing our knowledge up to date through the medium of two years' observations by a naturalist on the spot.

The whole series is printed in the excellent style and format that one expects from the Cambridge University Press. There is a large list of Corrigenda, but the reviewer is informed that this is due to hurried publication of the list of stations for the benefit of the research workers. In every other respect the work sets a high standard, and if the present level of authorship and presentation is maintained, the Reports of the *Discovery* Expedition should compare very favourably with those of the best of its predecessors, which is high praise indeed. R. E. P.

ARTISTS IN STRING. String Figures, their regional distribution and social significance. By K. HADDON (Mrs. O. H. T. RISHBETH). *London: Methuen & Co.* 1930. 8 × 5 *inches; x + 174 pages; and illustrations.* 6*s*

In so far as amusements and games are influenced by environment they must be of geographical interest. Amongst the most curious of these are String Games, or Cat's Cradles, usually associated with child life. But they have in recent years been seriously studied by travellers and anthropologists, who have come across them in many different parts of the world. They have excited interest for two reasons, their meaning and their geographical distribution, and may therefore possibly throw some light on the working of the human mind in relation to its environment, and the connections and movements of peoples. Their geographical distribution is very wide, for they have been observed in North and South America, the Eastern Asiatic Fringe, the Pacific Islands, Papua, Australia, and West, East, and Central Africa. But they are not found over the greater part of Eurasia. From which it follows that they are for the most part related to the darker races of mankind. In other words, they are characteristic of primitive peoples. In exemplification the author shows how these games are played by the native inhabitants of five very different and widely separated areas, viz. Alaska, South-West North America, New Guinea, Northern Australia, and the Gold Coast of West Africa. A study of these shows how they are influenced by the environment, *e.g.* the cat's cradles of the Alaskan Eskimo represent such objects as a kayak, caribou, polar bear, fishing net, and seal holes. The Papuans copy the coconut palm, banana plant, turtle, and sago ball. On the Gold Coast the figures represent waves, rapids, reeds on a river-bank, and the native bellows.

A good deal of imagination is often required to recognize in these figures the objects they are supposed to represent. The primitive mind apparently sees what is hidden from the civilized individual. This may explain the author's remark that civilization kills Cat's Cradles. However, admitting that the figures do represent the objects named, the influence of the environment is striking, and it can hardly be doubted that they are of indigenous origin in many different areas, and have not sprung from one centre. This is not to be wondered at considering the simplicity and universality of the apparatus required. And as the objects represented are naturally those well known and more easily recognized, they may be relied on as truthfully portraying the environment, life, and interests of the people making them. The author however points out that whilst the wide distribution of simple figures is easy to understand, the presence of certain complicated ones in widely separated areas is more difficult to explain.

There is some evidence from several different regions of a belief in the magical efficacy of the figures. But the author is called upon to justify the title of her book, and she asks whether string figures are a true form of representative art, conscious imitations of real objects executed in string, or whether they are merely child's play, make-believe string fantasies with names attached. There can be little doubt that the simplest and most primitive forms are the latter; but there are others not so simply explained, those for example showing memorising and repetition. "The more-developed figures are so complicated, and their construction so lengthy that at first sight it seems marvellous they could ever have been invented, and still more marvellous that once done they could ever be recaptured." An interesting feature of these games is the opportunity they offer of showing by a series of figures a developing scene, of telling a story as it were. It becomes a case of moving figures illustrating a tale. In view of these facts, can it be denied that a distinct element of Art is involved? E. A. P.

THE MONTHLY RECORD

INTERNATIONAL GEOGRAPHICAL CONGRESS 1931

In accordance with the decision of the International Geographical Union at its Cambridge meeting in 1928 the next International Geographical Congress will be held in Paris in 1931. We have received from Professor de Martonne, General Secretary to the Congress, a programme and conditions for membership. The dates selected for the meeting are from Wednesday 16 September to Thursday 24 September 1931, and the seat of the Congress and of the Secretariat will be at the Institut de Géographie de l'Université de Paris, 191 Rue Saint Jacques, Paris V^{e}. The programme of subjects for consideration includes the seven questions which have been under investigation by special commissions appointed or reappointed by the General Assembly at the Cambridge meeting in 1928 (see 'Report of the Proceedings of the International Geographical Congress, Cambridge 1928' (1930), pp. 42–49). The reports, which will be published by the commissions before the Congress in Paris, will form the basis of the discussions. A list is also given of other subjects which may be brought up for discussion if notice is sent in beforehand that contributions towards them will be submitted. Under the heading of Topography and Cartography are given high mountain topography; aerial phototopography; cartographical representation of topographical features; suggestions for rapid methods of mapping in tropical regions; proposal to publish every three years, on the occasion of the I.G.C., a résumé of the topographical and cartographical work of the geographical services of the different states; and presentation of special cartographical work. Under Physical Geography the subjects suggested are rivers of glacial origin; erosion modelling in tropical regions with a dry season and in hot regions without a well-marked dry season; probable or possible river captures; continental dunes; and the following, all with special reference to Europe and in particular to France: the definition and study of local climates; tertiary surfaces of peneplanation; karst and normal erosion. Under Biogeography are given the influence of man on the distribution of living things; the origin and dispersion of certain cultivated plants; and under Human Geography the localization of industries; urban agglomerations; the distribution of human settlement in tropical regions; means of rapid transport in tropical regions; irrigation in countries of small rainfall; methods of representation of population density; and geographical conditions in the control of rivers for navigation and the production of hydroelectric power, with special reference to Europe and in particular to France. In Historical Geography the questions for discussion are the origins of modern cartography; the cataloguing and study of ancient Itineraries, especially in France; the critical study of old maps; and the examination of unpublished journals of explorers since the seventeenth century.

A series of excursions, lasting about a week to ten days, are being arranged. Those preceding the Congress give a choice of the Jura and Fore-Alps of Savoy with Prof. Cholley and M. Chabot; the south-east Massif Central with Prof. Baulig; the Auvergne with Prof. Arbos; and the Alps of Dauphiné with M. Blache. After the Congress they consist of an excursion from Paris to Rouen and Le Havre with Prof. Demangeon; the Seine valley and coast of the Somme Bay to the North Sea with Prof. Chaput and M. Briquet; Provence of the Rhone valley and coast with Prof. Bénévent; and Algeria with Prof. Bernard.

In the invitation notice sent out by the General Secretary with a form of application for membership it is stated that "In order to be registered as a member of the Congress the requisites are: (1) To belong to a Geographical Association

or to an Institution or a Service whose activities bear some relation to Geography. (2) To fill the enclosed form and send it to the Secretariat of the Congress. (3) To pay at the same time the registration fee of 125 French francs." Members of the Congress may also have relatives registered as members, if they fill in and return a special form together with the fee of 125 francs for each person to be registered. The Organizing Committee ask for notice as early as possible from persons intending to join, with an indication of which excursion each member may wish to attend. For the latter they give a somewhat inconvenient limiting date, the end of 1930, after which they will be unable to guarantee participation in any of the excursions before or after the Congress.

THE *SÖLLE* OF MECKLENBURG

This term has been adopted in Germany to denote the remarkable small depressions, mostly filled with water, with which large areas of the North German Lowland are positively riddled—so great is their number. They are entirely unconnected with any surface drainage system and are isolated phenomena bearing no relation to the existing surface forms. For years their origin has been discussed without any general agreement having been reached. Strangely enough few have undertaken a thorough examination of the Sölle, and mistaken ideas have been current even among scientific men: it has been generally supposed, for example, that they are remarkable for great depth, and they have been wrongly described as "funnel-shaped." The problem has lately been attacked by Dr. Walther Röpke, who has sounded a number of the Sölle, and has described his results and conclusions in a monograph published last year at Rostock. The region in question, which in its present form is the creation of the ancient ice-sheet, is occupied by three belts of country running from north-west to south-east: the Baltic terrace in the north-east, the lake-plateau in the centre, and the lowland in the south-west and south, the central belt being bordered north and south by the well-marked end-moraines of the ice-sheet. The Sölle are found to be saucer-shaped hollows of no great absolute depth, though some are deep relatively to their size. They are most numerous in the area representing the old ground-moraine, becoming fewer in the end-moraine tracts, and practically absent in the parts covered with sand. Quite a number of theories have been put forward to account for their origin. One has attributed this to rock solution and sinking of the surface above; another to whirlpool action in streams due to the melting ice; a third to the breaking up of the ice into blocks, some of these persisting for a time as "dead" ice, at the ultimate melting of which holes would be left. These and others are discussed in turn by Dr. Röpke, who finds that all involve assumptions which are not justified by the facts. He propounds a theory of his own, which comes nearest to the ice-block hypothesis, but differs in its explanation of the processes involved in the formation of the ice-blocks. Stress is laid on the relation shown to exist between the Sölle and the undisturbed ground-moraine. This is now recognized as having formed the lowest stratum of the ice-sheet, which would possess but slight mobility, so that with the constant addition of fresh material above portions of the ice would become imbedded in a stationary mass. After the disappearance of the ice-sheet this buried ice would melt gradually, the surface above sinking with the process. This is held to fit in with all the features observed.

The true Sölle are never of artificial origin, though their present steep margins are ascribed to agricultural operations in their vicinity. They are often found in the neighbourhood of villages, which were no doubt often placed near them for convenience' sake. Somewhat similar ponds may occupy the sites of old marl-pits, but these can generally be distinguished by their form.

LOCAL EXPOSURE IN MOUNTAINS

In the *Revue de Géographie Alpine* (t. xviii, 1930) M. Roderick Peattie deals with "La Question de l'Adret et de l'Ubac," the terms respectively denoting the sunny and shaded slopes of a valley. He points out that insufficient care is exercised by geographers in interpreting differences in the altitude of vegetation on different slopes, since they are far too much inclined to read into these differences the sole factor of exposure to sunshine. This of course is the most important factor, because it often happens that certain slopes catch the insolation perpendicularly according to the season of the year whilst others will get no sun at all at certain seasons. But other factors are exposure to prevailing winds, geology, and interference by man. The geological factor is very significant, and neglect to consider it leads to erroneous judgment as to the effects of climate. Thus in the Alps the chalets attain a few hundred metres higher elevation on the gentle drier slopes of crystalline rocks than on limestone. On the other hand as the crystalline rocks weather into a cold damp loamy soil, the beech does not climb so high as on the limestones. Economic factors also are liable to disturb the distribution of vegetation on mountain slopes which would obtain if varying exposure to the sun were the only factor involved, so that altogether careful judgment needs to be exercised.

Comparison is made between the sunny and shaded sides of valleys and of mountain ridges. In the latter case the climatic contrasts are sharper. In the Sierra Nevada of Spain there are wide contrasts between the northern and southern slopes which, in the absence of much difference in geology or topography, may be attributed entirely to climate. Thus according to the measurement of Boissier made as long ago as 1837, on the south slopes, where the climate is African, the vine reaches 700 feet, the walnut 500 feet, the olive 1700 feet, the fig 100 feet, and rye 600 feet higher than on the northern, which is not only shaded from the sun but also exposed to cold and stormy winds from the central plateaux. M. Peattie argues that the above-quoted altitude differences for different species prove that the sunshine factor cannot be the only one. We agree that it is the totality of climatic elements that counts in these cases, but there is no reason to suppose that the reaction to sunshine of the several species must necessarily be the same as the argument would seem to imply.

RETURN OF DANISH OCEANOGRAPHICAL EXPEDITION

In the *Journal* for July 1928 (vol. 72, p. 95) there appeared a note announcing the departure from Copenhagen of the Danish research ship *Dana* on a two-year cruise round the world via the Panama Canal, the East Indies Archipelago, and the Red Sea. On June 30 last the *Dana* returned to Copenhagen, and through the courtesy of the Foreign Office we have now received a summary of some of the results of the expedition, together with a copy of a sketch-map showing the course of the voyage which covered some 65,000 sea-miles. According to this sketch-map the *Dana* did not return by the Red Sea, as was originally intended, but after crossing the Indian Ocean to the east coast of Africa, returned to Europe via the Cape and the South Atlantic. During the whole cruise the *Dana* crossed the equator twelve times and visited six hundred and sixty-one stations. The chief object of the expedition is stated to have been to carry out the investigations of Professor Schmidt, leader of the expedition, into the life and migrations of the eels of the Pacific and Indian Oceans, and to prove that their breeding habits and biology are identical with those of the Atlantic (*i.e.* the European and the American) eel. In preparation for this work Professor Schmidt visited Australia, New Zealand, and Tahiti two years ago and was then able to distinguish eight species of fresh-water eels in the South Pacific, among them one of gigantic dimensions in the mountain

lake of Vaihiria in Tahiti. As a result of the voyage just concluded, Professor Schmidt has found and identified the larvae of six species of eels which have hitherto been unknown to science, and which find their way into the rivers of the South Sea Islands and of the countries around the Indian Ocean, the Australian Ocean, and East Africa. He has discovered that their spawning migrations correspond with those of the Atlantic eel and are regulated by the depth, salinity, currents, and temperature of the water.

The expedition also carried out extensive research into the physical and chemical conditions of the sea and made a large collection of marine fauna and plankton life from great depths.

INVESTIGATIONS OF THE GREENLAND ICE

In preparation for more extended researches in 1930 and 1931, a German party under Dr. A. Wegener last year undertook preliminary investigations in the neighbourhood of Umanak in West Greenland, with the object of searching for the best line of ascent to the inland-ice, and of testing the methods of research proposed. In spite of its provisional nature it gained results of positive value, which have been described by Dr. Wegener and his assistants (Drs. Georgi, Loewe, and Sorge) in the *Zeitschrift* of the Berlin Geographical Society, 1930, Nr. 3/4. The party left Copenhagen at the end of March, and at Holstenborg picked up their 30-foot motor boat which was to form their headquarters through the summer apart from the time occupied in sledge expeditions. At Jakobshavn they secured the services of the Greenlander Tobias Gabrielsen, who had been an associate of Dr. Wegener during the *Danmark* expedition of 1906–08. Before proceeding to their final destination the explorers made a preliminary trip inland from Disco bay, which is open a month earlier than the fiords about Umanak. The notes on the methods and equipment adopted will be of much use to other parties undertaking similar work. The latter was kept as light as possible, and the four sledges were hauled by the Europeans themselves during this first trip. The point of ascent was that chosen by the Quervain expedition of 1912, but the journey over the ice-cap was made in a north-east direction, the terminal point, 150 km. from the starting-point, lying at an elevation of 2090 m.

For the main trip dogs were used to draw the sledges, and a party of Greenlanders was engaged to transport the loads up the steep ascent to the inland-ice. It was only after a vain search in various directions that a route at all suitable for a laden party could be found, this lying up the Kamarujuk glacier, at the head of the fiord of the same name. From a depot on the ice at an altitude of 1590 m. Drs. Wegener and Georgi struck inland slightly north of east, and in six marches reached an altitude of 2500 m., 210 km. from the edge of the ice-cap. Strong winds were encountered which proved a hindrance on the outward route, though of some help on the return. Meanwhile the two others had carried out a trip to the north nearer the edge of the ice. Throughout all the journeys careful observations of the structure and composition of the ice and of the passage from nevé to massive ice were made, as also of the passage from " inland" to "mountain" ice at the edge of the sheet. The state of the glaciers near the coast was recorded for comparison with past or future observations. One was photographed from the same standpoint as by Von Drygalski many years previously. On one occasion the party were witnesses of the imposing spectacle of the bursting of a glacier lake, and on another their camp narrowly escaped being wrecked by a stone avalanche. A special object of the expedition was to test the newly elaborated method of determining the thickness of the ice by seismometric observations, an artificial "ice-quake" being effected by an explosion at a fixed distance from the seismograph, and the times of arrival of the horizontal and deep-seated waves compared. Special sections deal with these and other observations.

QUEENSLAND

LOW ISLES

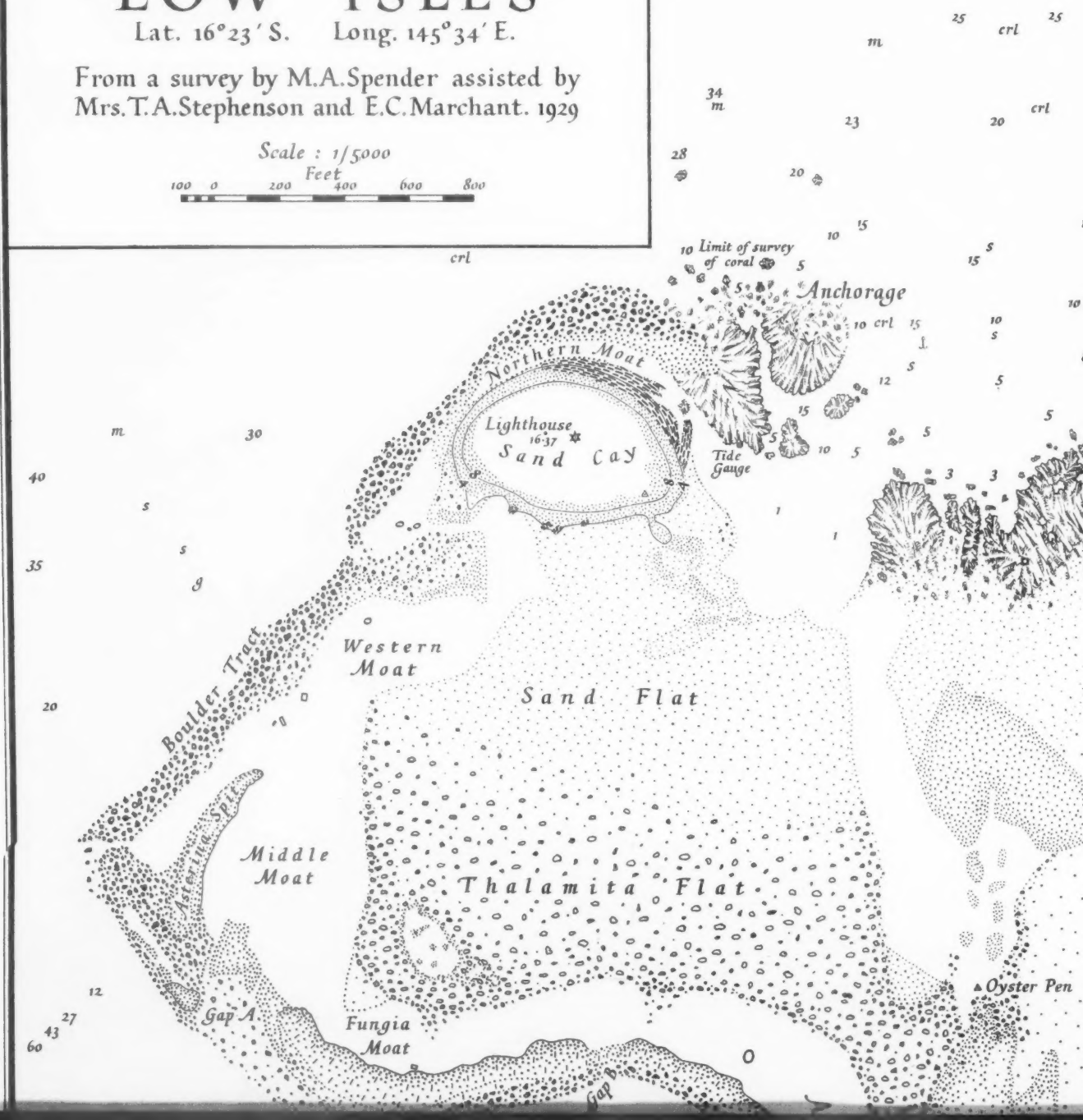
Lat. 16°23′ S. Long. 145°34′ E.

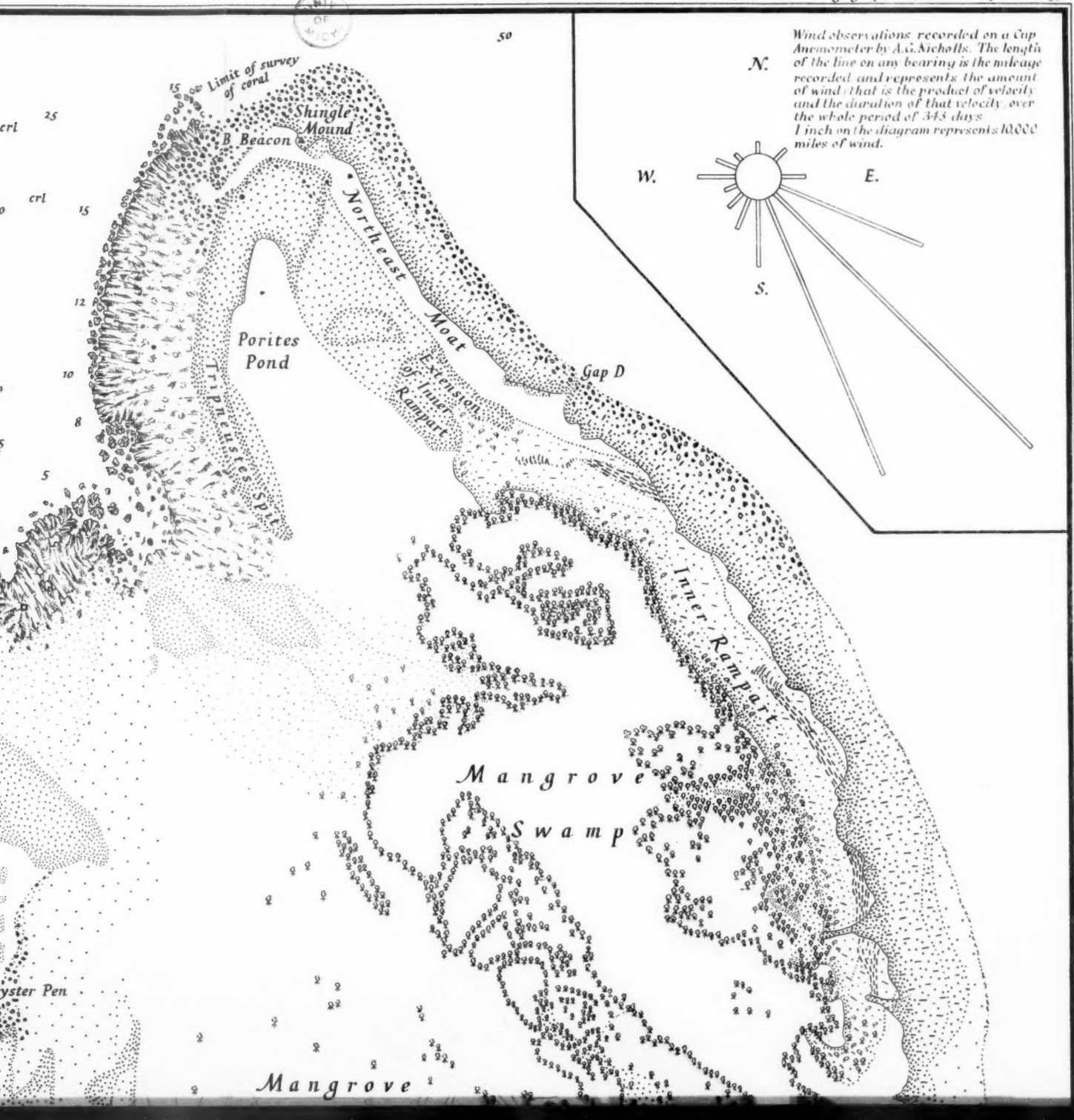
From a survey by M.A.Spender assisted by Mrs.T.A.Stephenson and E.C.Marchant. 1929

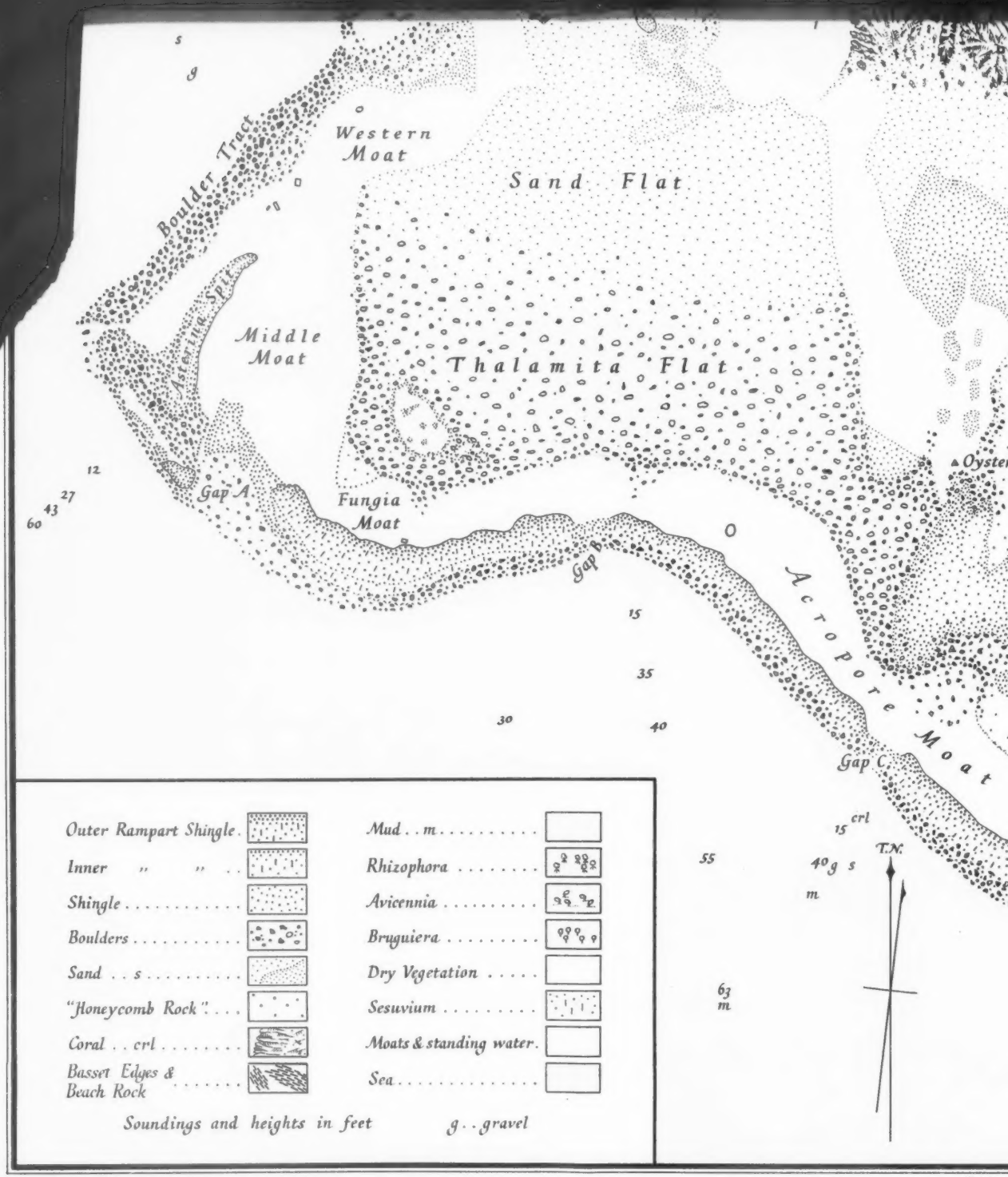
Scale : 1/5000

Feet

100 0 200 400 600 800




Wind observations recorded on a Cup Anemometer by A. G. Nicholls. The length of the line on any bearing is the mileage recorded and represents the amount of wind; that is the product of velocity and the duration of that velocity over the whole period of 343 days.
1 inch on the diagram represents 10,000 miles of wind.
N.
W.
E.
S.
50
Limit of survey of coral
15
25
crl
Shingle Mound
B Beacon
Northeast Moat
Extension of Inner Rampart
Porites Pond
Tripneustes Spit
Gap D
Inner Rampart
Mangrove Swamp
Mangrove
yster Pen


Boulder Tract
Western Moat
Sand Flat
Asterina Spit
Middle Moat
Thalamita Flat
Gap A
Fungia Moat
Gap B
Actopore Moat
Gap C
Oyster
T.N.
Outer Rampart Shingle
Inner " " "
Shingle
Boulders
Sand . . s
"Honeycomb Rock"
Coral . . crl
Basset Edges & Beach Rock
Mud . . m
Rhizophora
Avicennia
Bruguiera
Dry Vegetation
Sesuvium
Moats & standing water.
Sea
Soundings and heights in feet
g . . gravel

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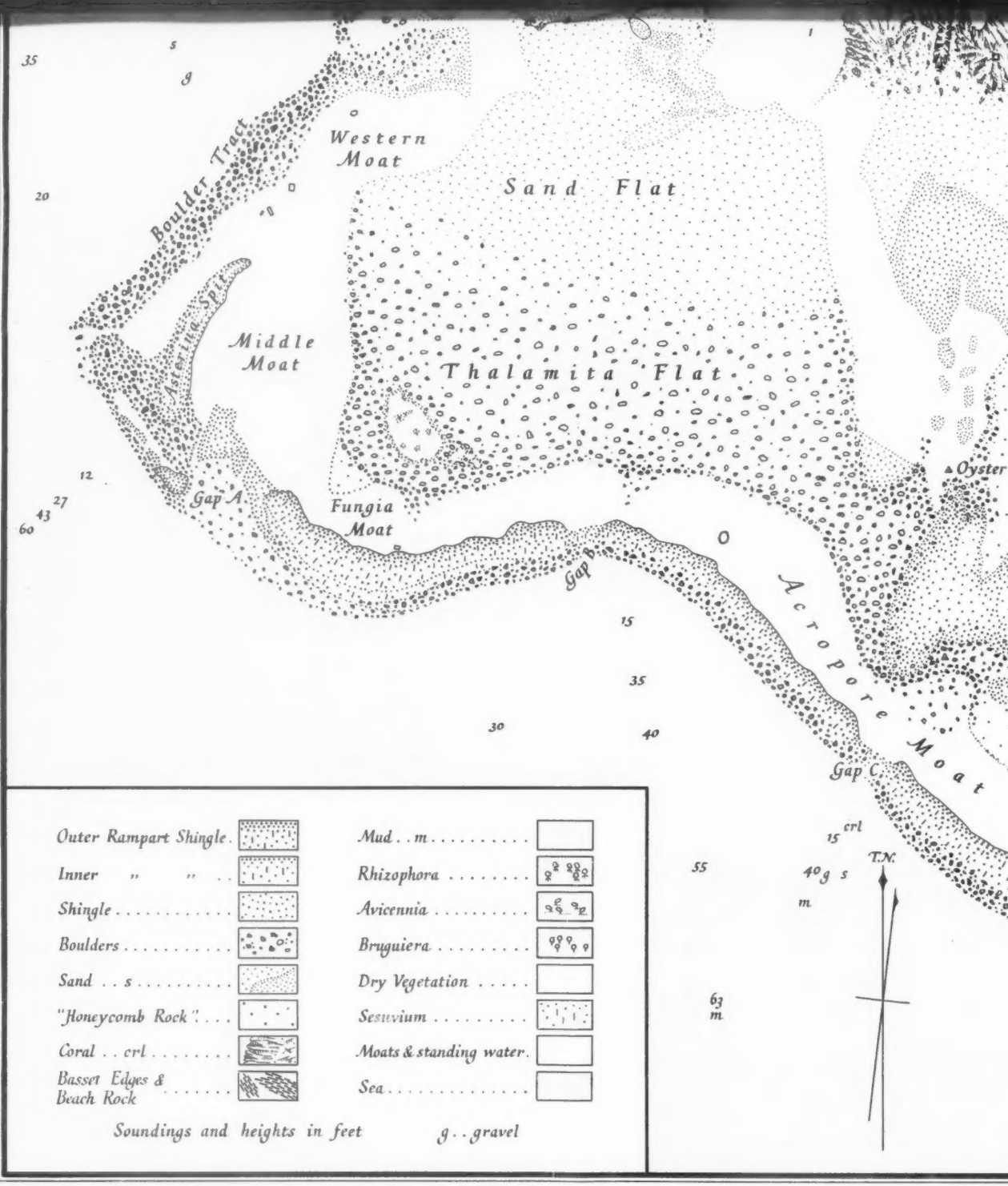
GREAT BARRIER REEF EXPEDITION
Spender


Boulder Tract
Western Moat
Sand Flat
Middle Moat
Thalamita Flat
Gap A
Fungia Moat
Gap B
Actopore Moat
Gap C
Oyster
T.N.
Outer Rampart Shingle
Inner " "
Shingle
Boulders
Sand . . s
"Honeycomb Rock"
Coral . . crl
Basset Edges & Beach Rock
Mud . . m
Rhizophora
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Dry Vegetation
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GREAT BARRIER REEF EXPEDITION
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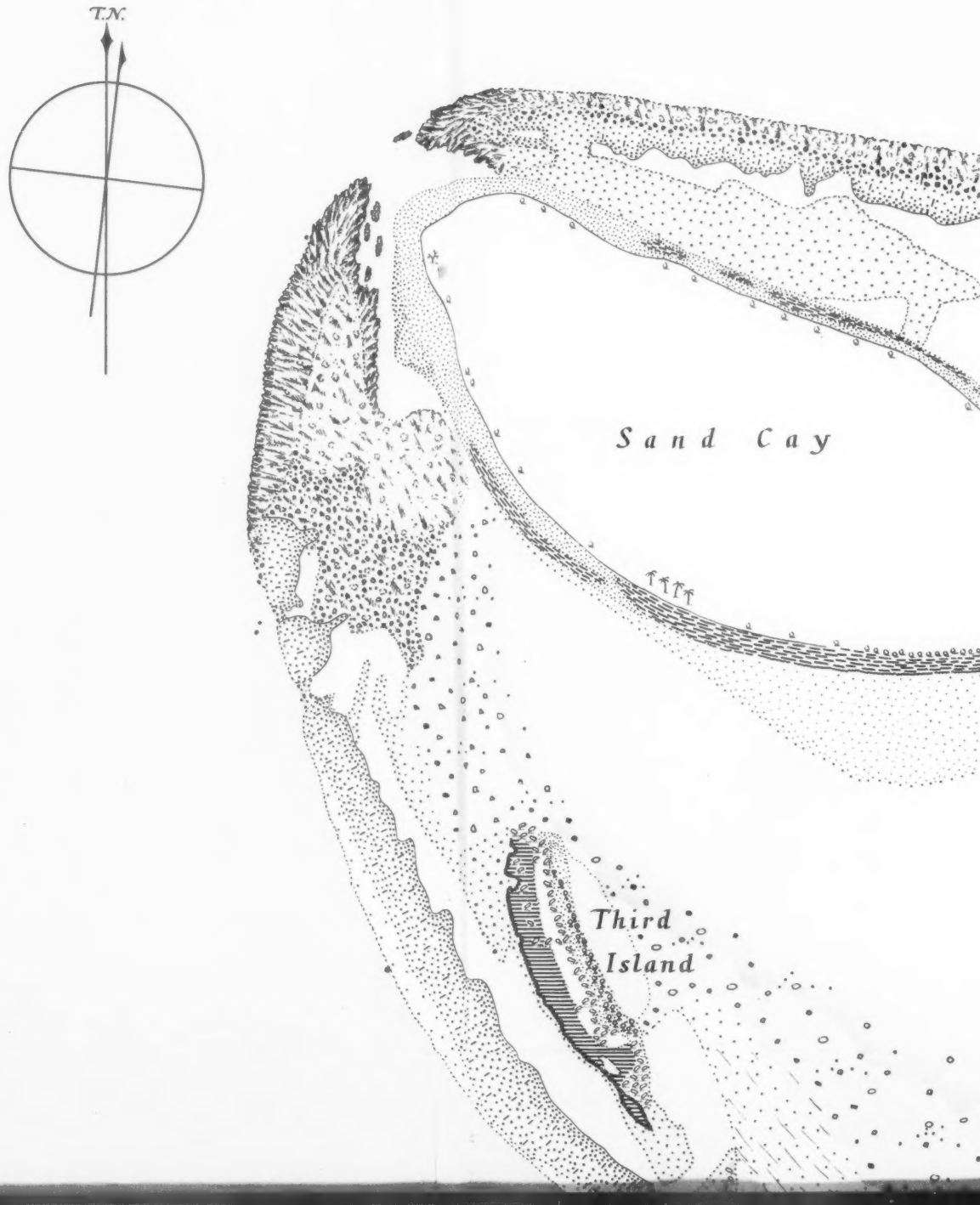

T.N.
Sand Cay
Third
Island

QUEENSLAND

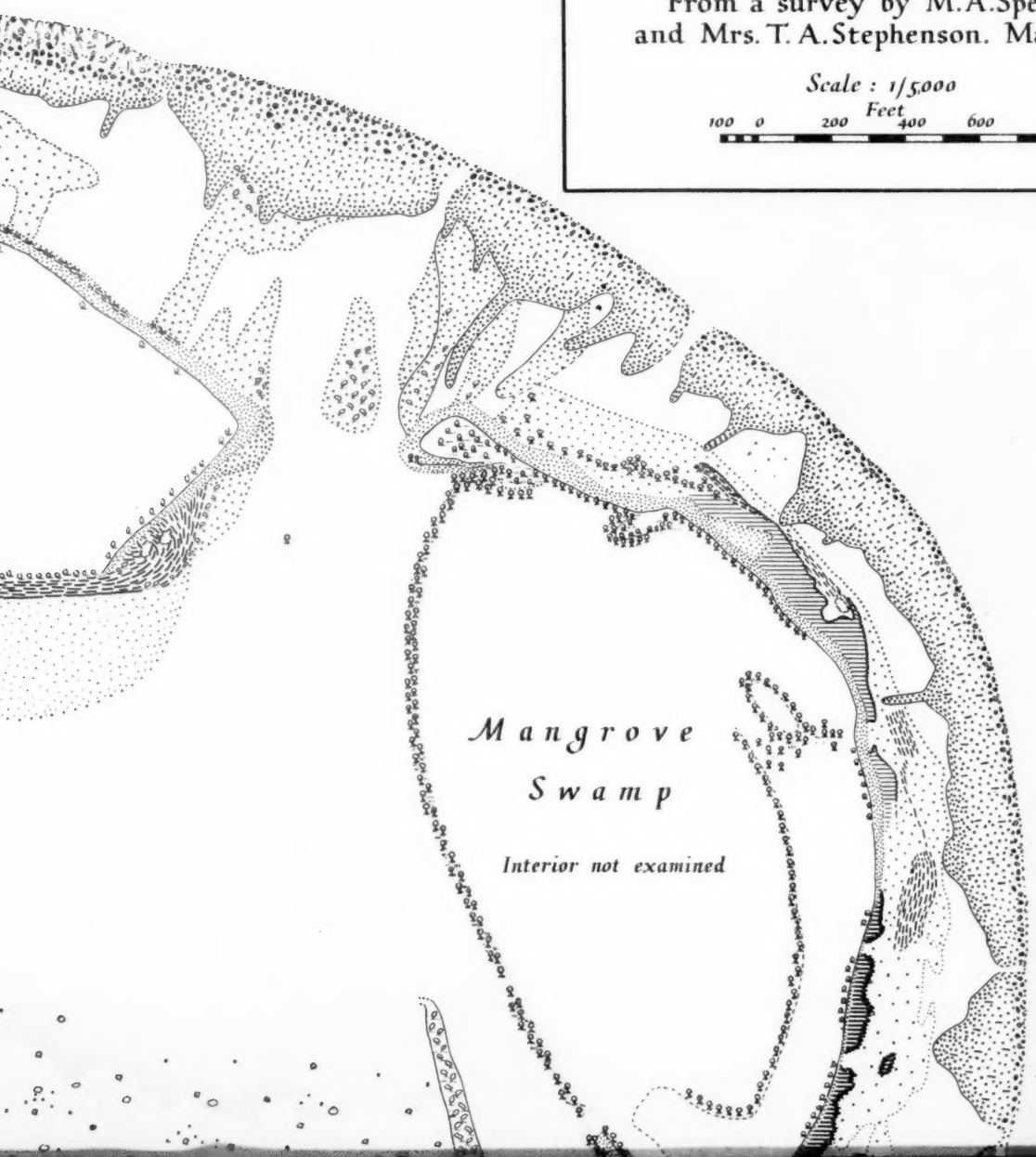
THREE ISLES

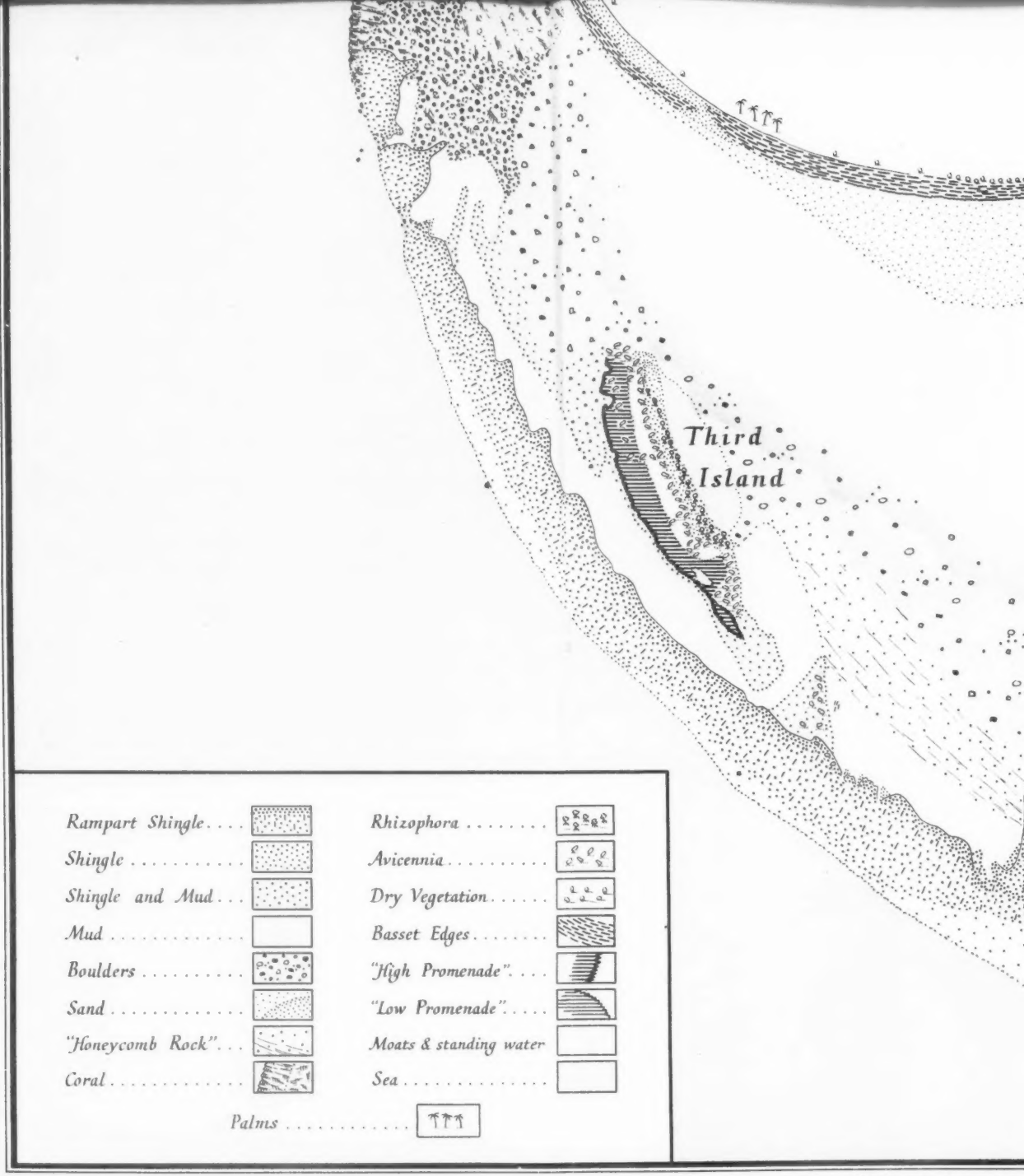
Lat. 15°07′ S. Long. 145°25′ E.

From a survey by M.A.Spender
and Mrs. T. A.Stephenson. May, 1929.

Scale : 1/5000

100 0 200 Feet 400 600 800





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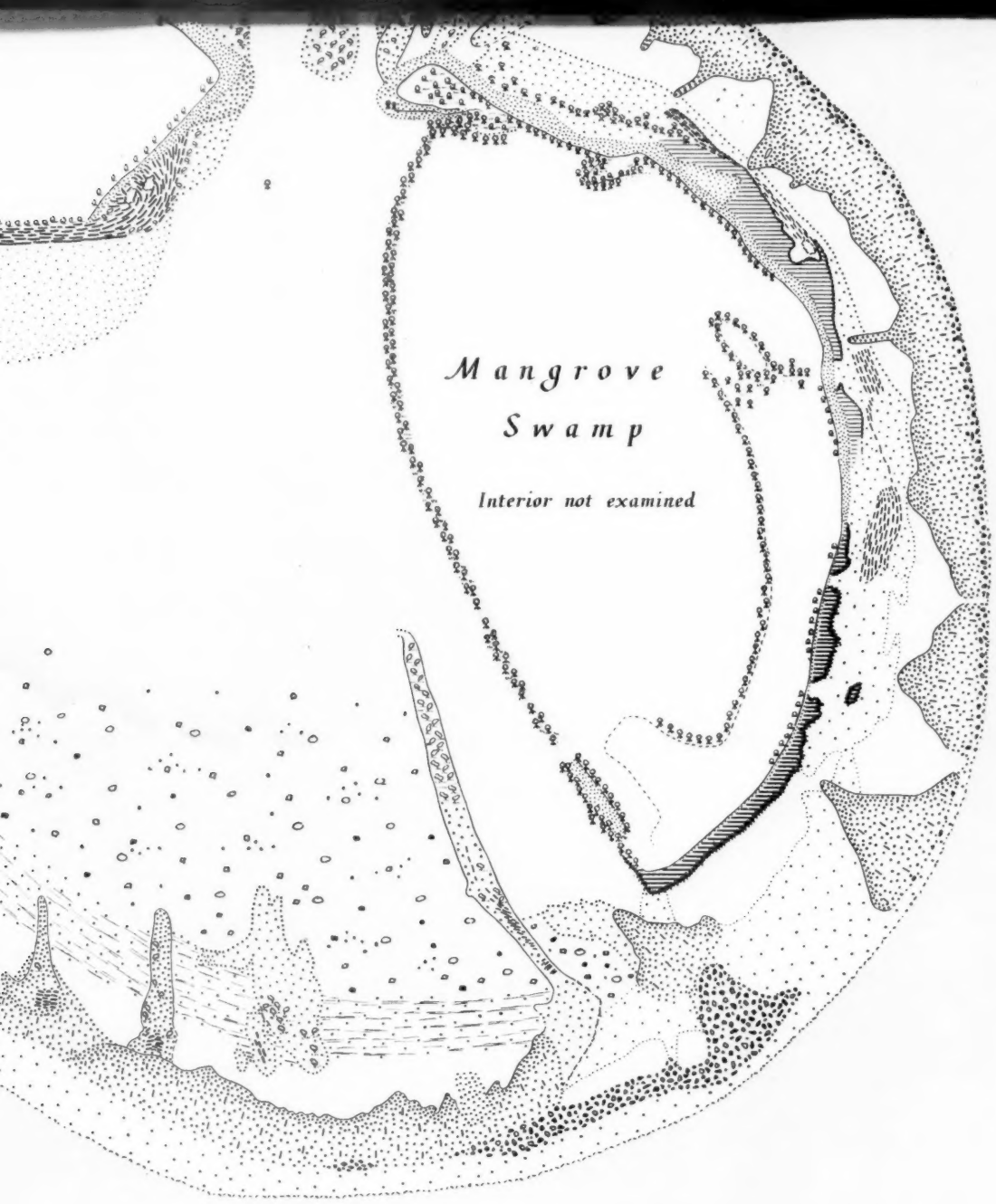

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GREAT BARRIER REEF EXPEDITION
Spender